The Journal of Bone and Joint Surgery

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The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
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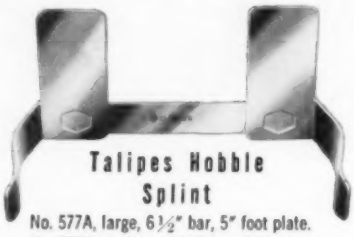

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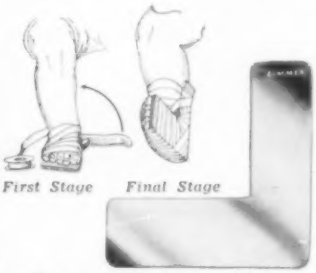

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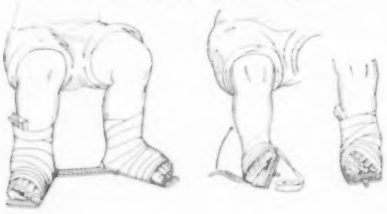

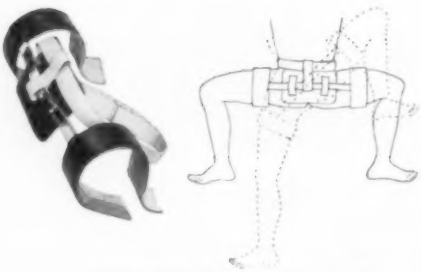

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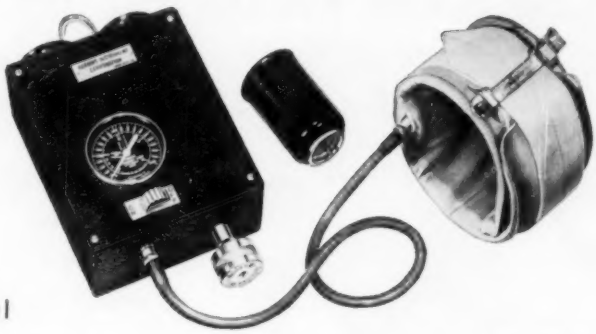

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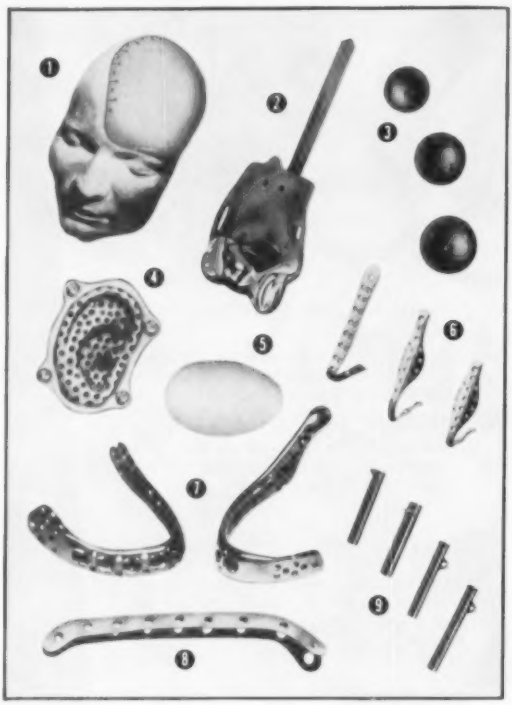

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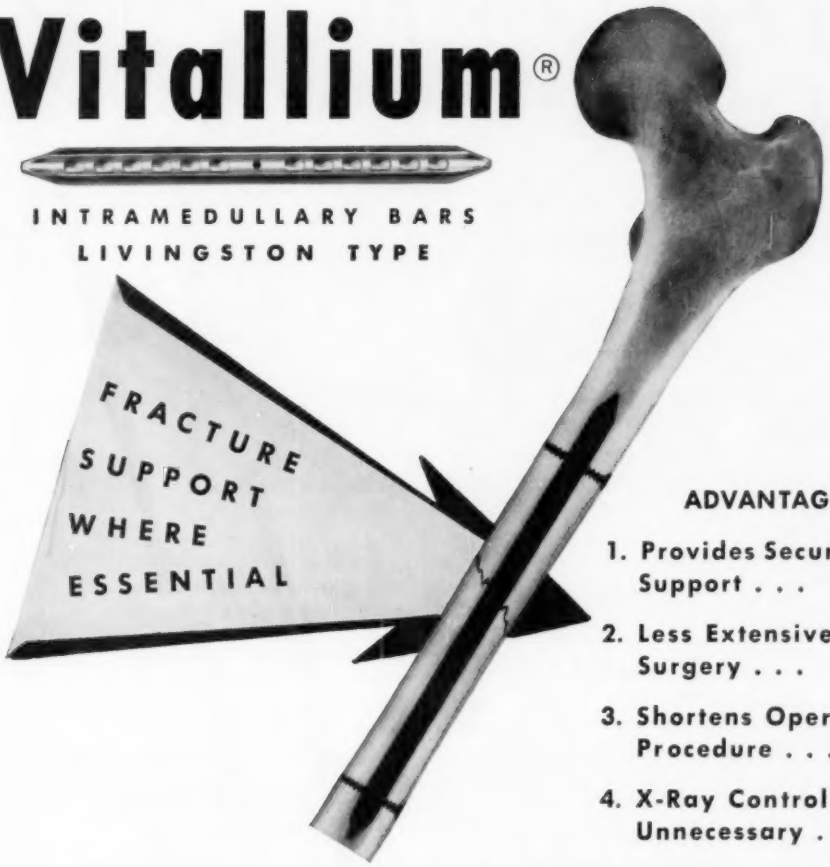

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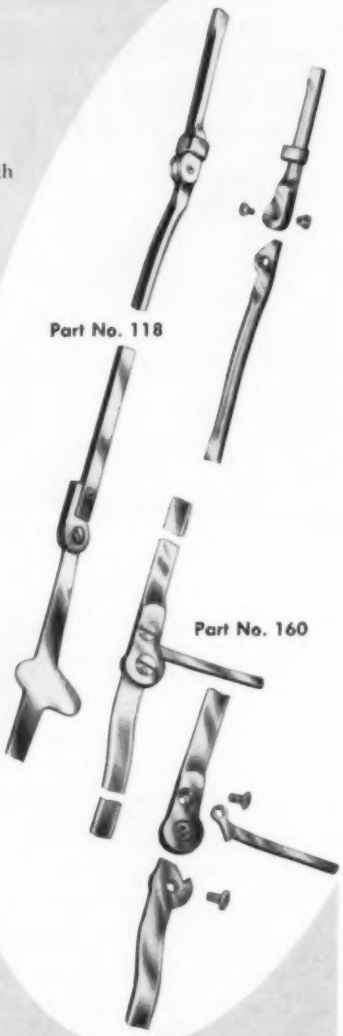

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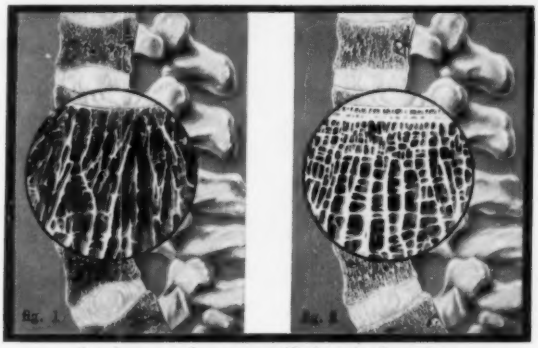

lumbar vertebrae, magnified sagittal sections

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Here's **ASSURED SAFETY** in a saw that both oscillates and rotates!

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Strap over instep holds heel down into place

RIGHT

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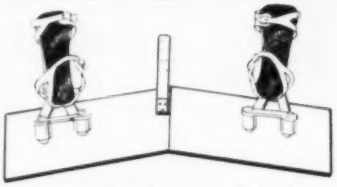

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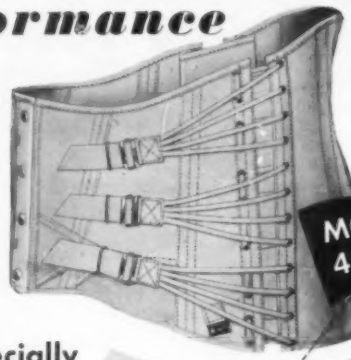

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*Gray, T. C. and Geddes, I. C., J. Pharm. and Pharmacol., 6:89-114 (February) 1954

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- Restores normal length of femoral head and neck. Eliminates torsion and tipping.
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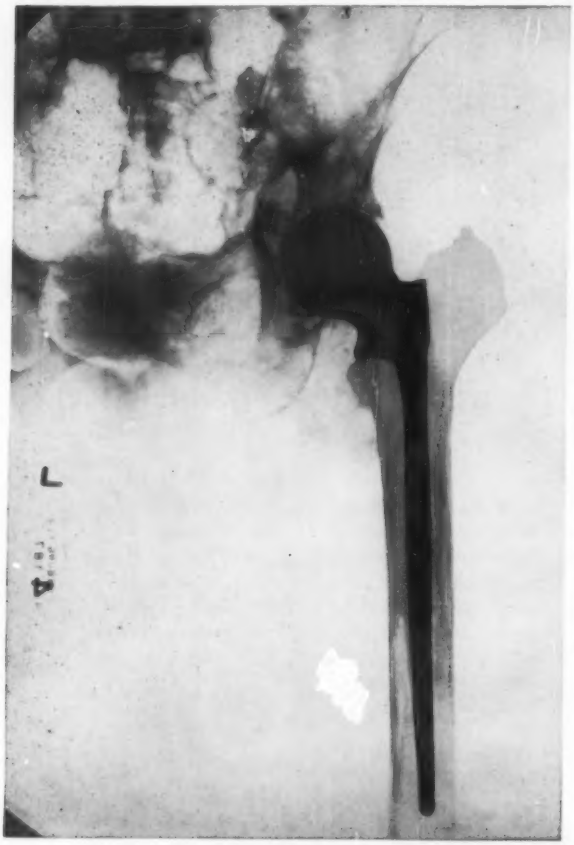

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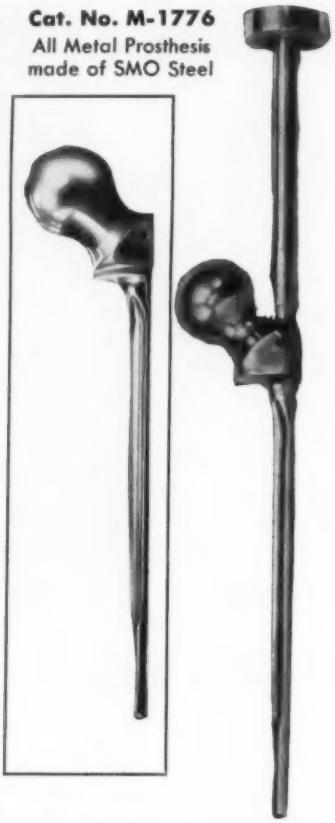

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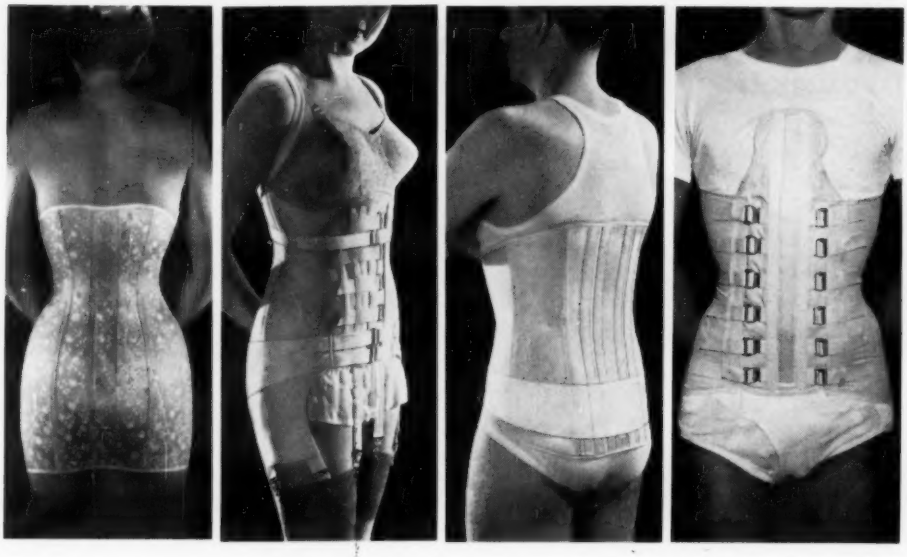

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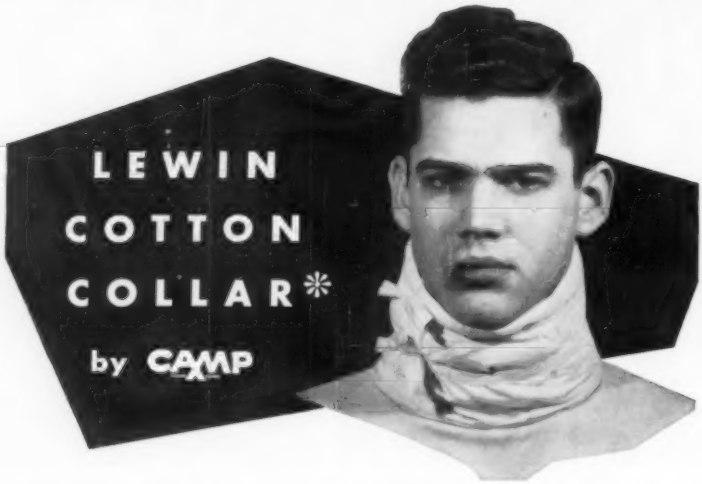

CAN BE USED IN CASES OF: arthrities, fibrositis, brachial neuropathy, radiculitis, the neck-shoulder-hand syndrome, muscle injuries and subluxation of vertebral articular facets.

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* *As described in THE JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION, Vol. 155, No. 13, July 24, 1954.*

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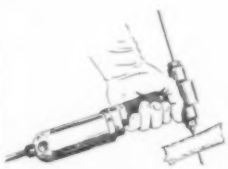

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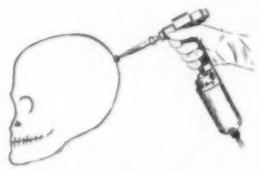

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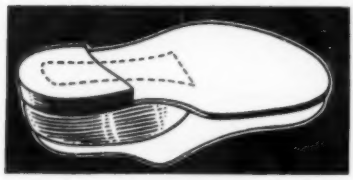

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Alden-Pedic lasts and shoes have been scientifically designed and tested to accommodate specific and general degrees of foot disabilities. Doctors who become familiar with the functional merit of this program will be glad to prescribe these shoes as a foundation in the treatment and correction of foot disabilities. We do not claim that these shoes will correct abnormal foot conditions, but they will provide the types of basic footwear necessary as a foundation in aiding foot trouble and in offering foot comfort. We know you will be glad to recommend them.

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1. Rigler, S. P. and Adams, W. E.: Experience with a new sprayable plastic as a dressing for operative wounds, Surg. 36:792 (Oct.) 1954. (University of Chicago Clinics, Chicago, Surgical Service).

2. Choy, D. S. J.: Clinical trials of a new plastic dressing for burns and surgical wounds, Arch. Surg. 68:33 (Jan.) 1954. (Bellevue Hospital, New York, Third Surgical Division—Dr. John Mulholland, chief).

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For clubfoot, fore-arm and other casts where an extremely fast-setting bandage is desired.

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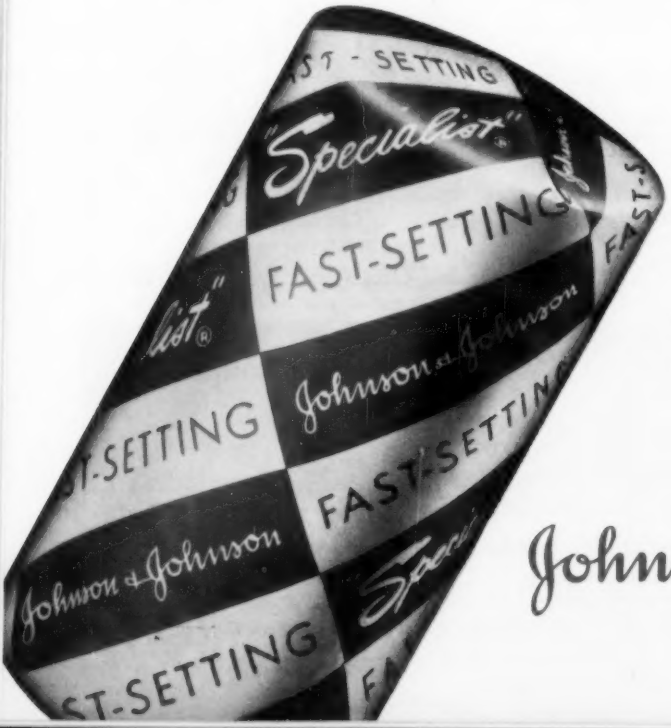

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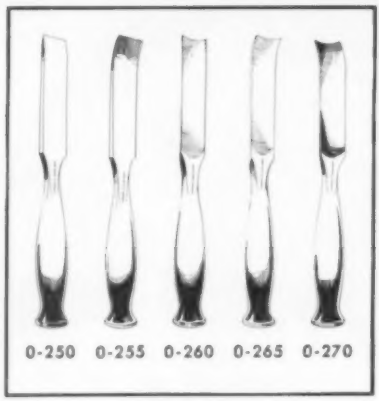

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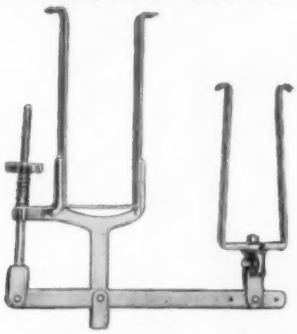

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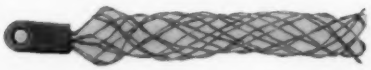

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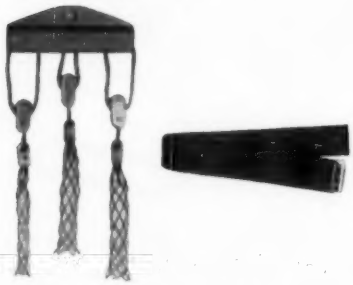

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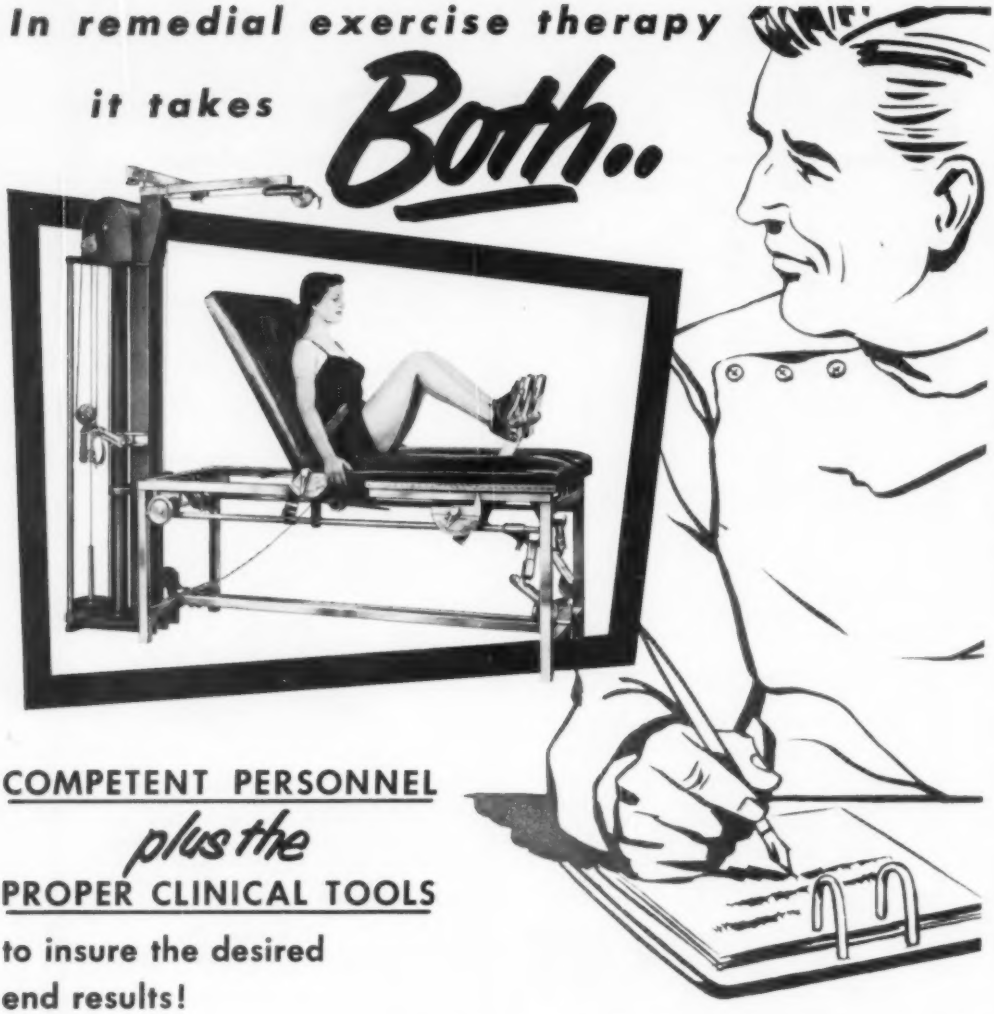

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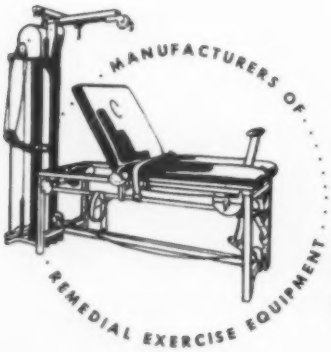

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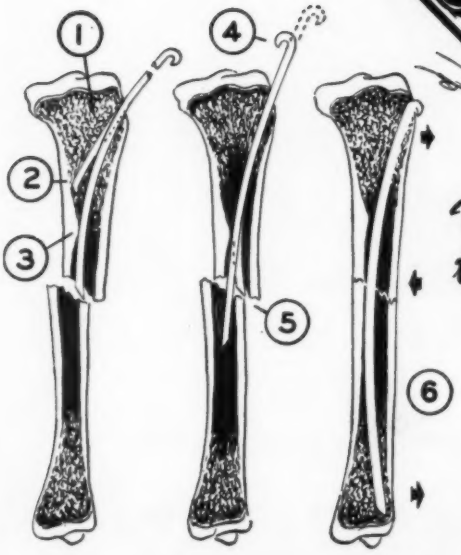

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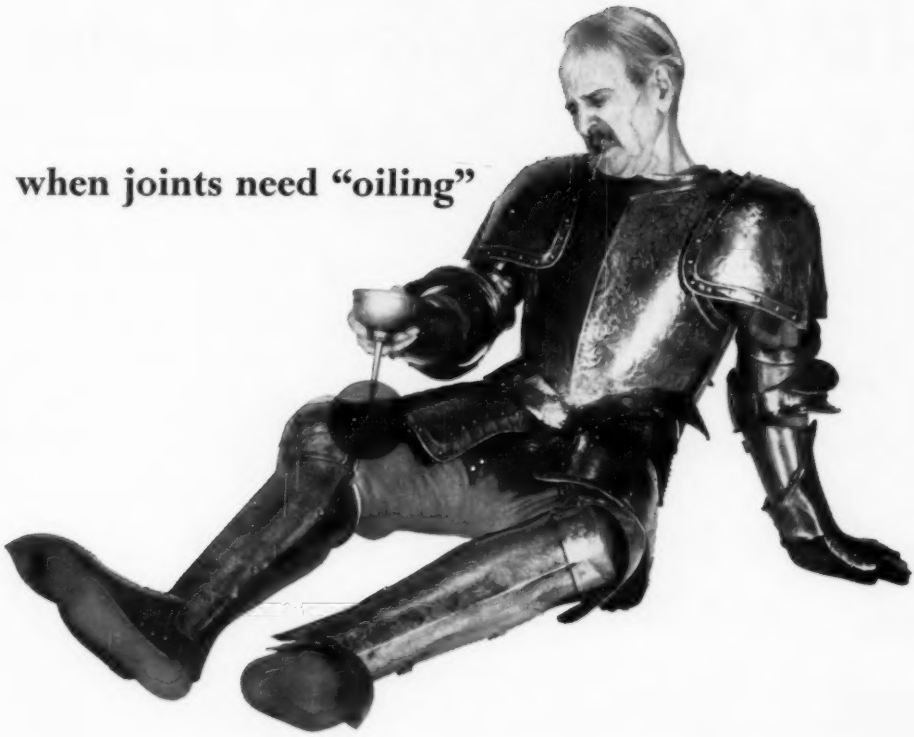

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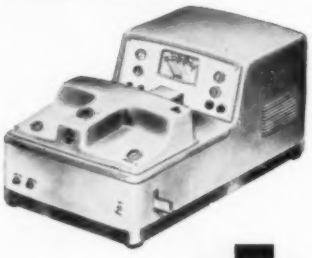

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As a result of cooperation with cineplastic research, HANGER has developed the "Cinematic" Arm, designed for application to patients with cineplasty operations. Principles of simplicity, durability, light weight, alignment, proper cosmetic appearance, and proper fitting of a comfortable socket have all been important considerations in the development of this new Cineplastic Prosthesis. In making the below-elbow prosthesis, utilizing a biceps motor, the socket and forearm shell are constructed over a plaster reproduction of the stump. A wrist coupling is fitted at the terminal end of the forearm shell.

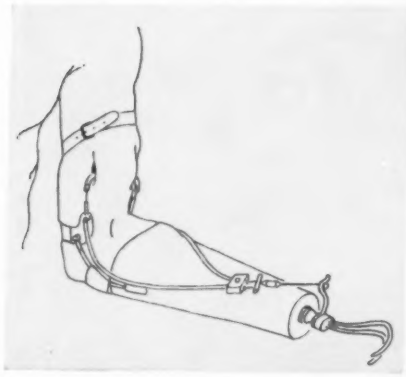

FIG. 1. Below-elbow cineplastic prosthesis with cables and terminal device fitted.

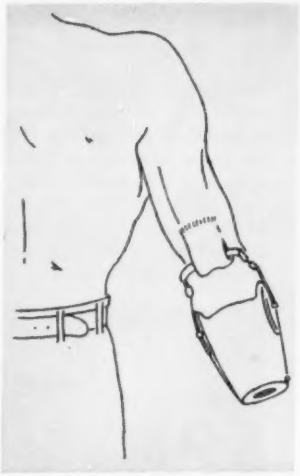

FIG. 2. Showing below-elbow prosthesis on stump with muscle tunnel pin in place.

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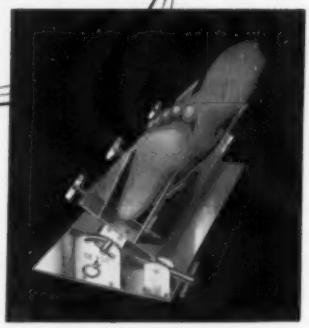
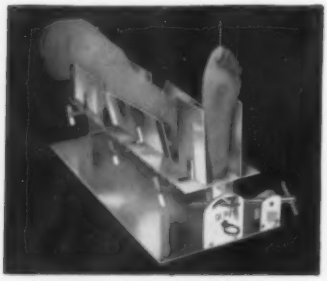
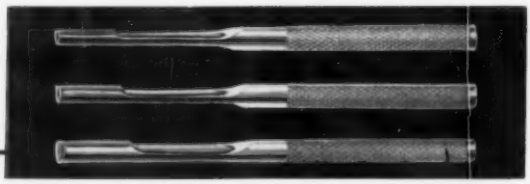


Another DePuy first, this leg immobilizing device allows portable x-ray unit to be placed in constant position, permitting lateral views of the hip to be taken without any movement of the patient. Shortens operative procedure, assures hip will be in correct position for each lateral film taken. Does not interfere with movement of fluoroscopic screen or x-ray spot film device. Eliminates chance of bending guide wires. Precision construction of stainless steel. Write for more information. No. 608.



DePuy Tendon Stripper

An aid in stripping tendons from bone. Semi-circular blade fits over bone. No. 580, Set of 3 sizes.



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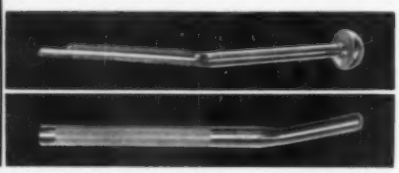

For left: No. 562A Complete with stem, ball and washer. (Specify diameter of ball, 1⅝", 1¾" or 1⅞").

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Bottom left: Driver for inserting, fits into hollowed portion at top of stem. No. 563.

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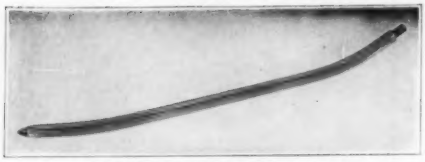

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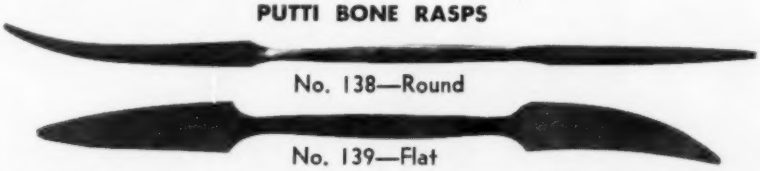

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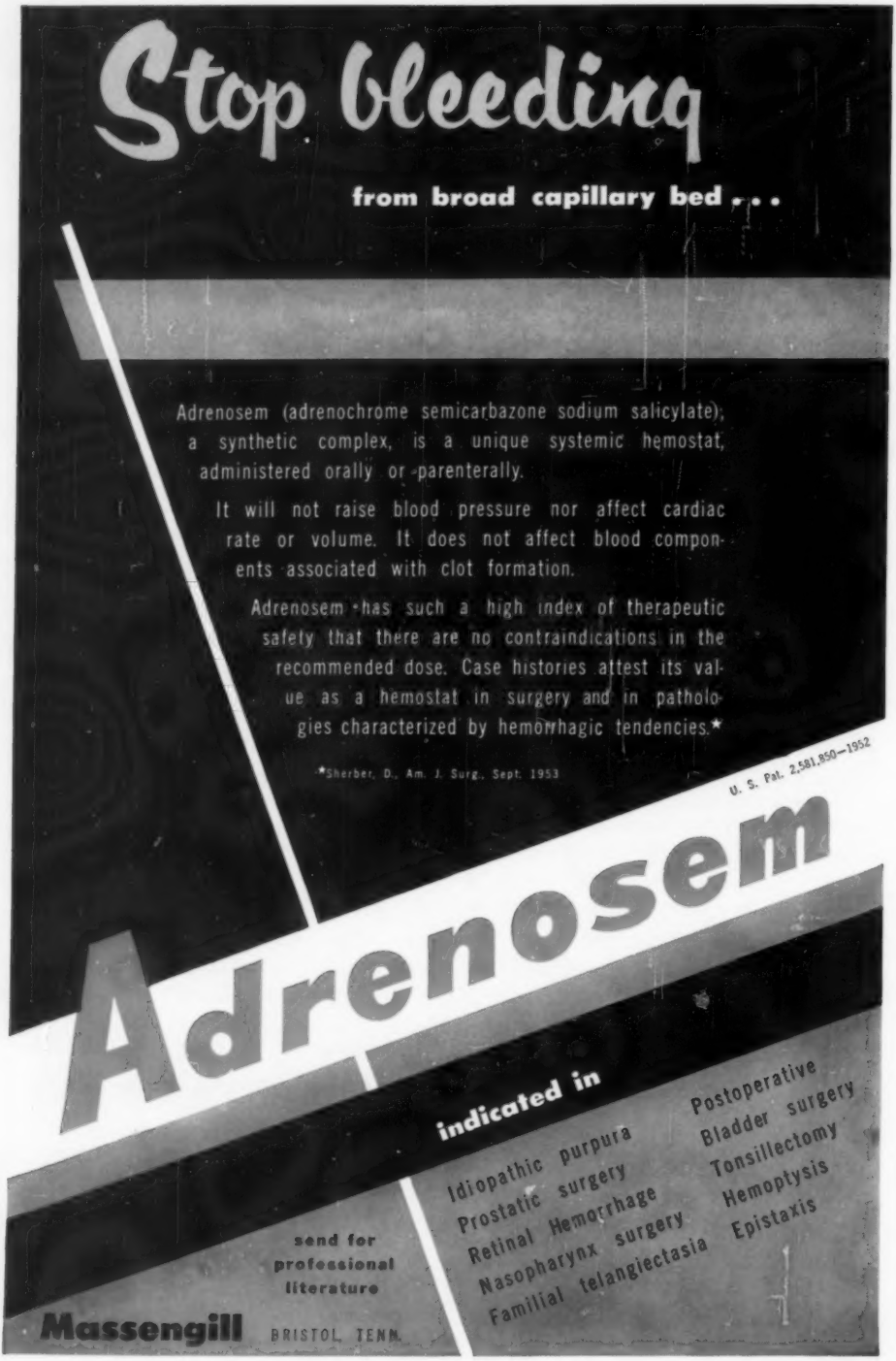
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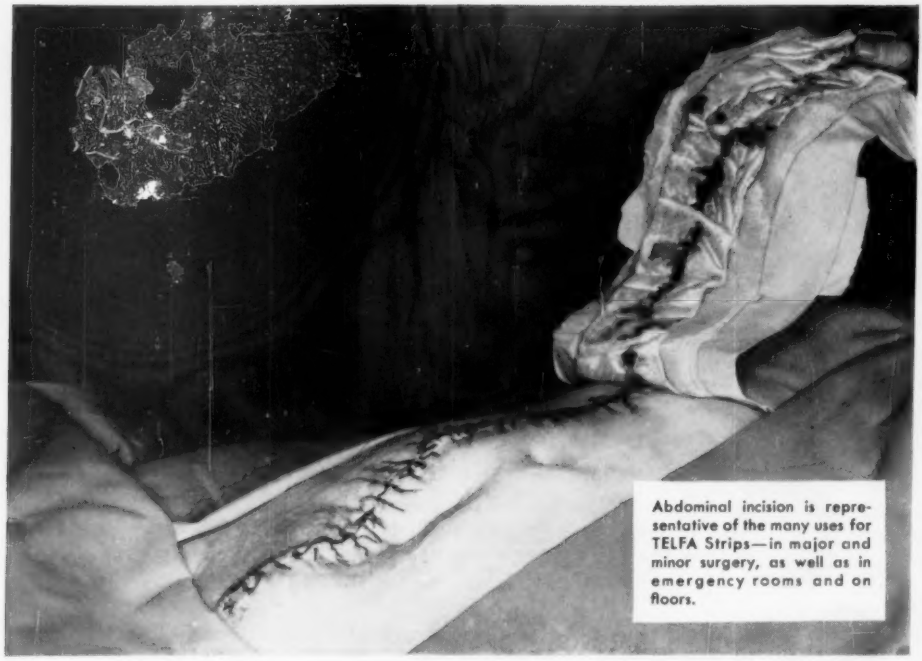

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AN ANALYSIS OF END RESULTS OF SURGICAL TREATMENT OF MAJOR INJURIES TO THE LIGAMENTS OF THE KNEE *

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Many years of experience in the treatment of major injuries to ligaments of the knee have led to the conviction that the best outcome can only be obtained by early meticulous surgical repair of every damaged ligament. Cases illustrating the excellent results which may be obtained by early surgery have already been reported.[1] In that report an urgent plea was made for the early suture of injured cruciate ligaments in particular. There had been considerable controversy concerning the necessity for this. Many had said that, provided the lateral ligaments were intact and provided that the quadriceps was completely rehabilitated, cruciate-ligament stability was not essential for a "normally functioning knee".

The material previously presented in support of the claim that early suture of injured cruciate ligaments is necessary included some twenty-five cases, all but two of them in athletes. Most of these men had a single type of injury, — namely, laceration of the medial collateral and anterior cruciate ligaments and of the medial meniscus. The injury was termed the "unhappy triad". While that series definitely showed that early repair was successful and that failure to repair the anterior cruciate ligament was disastrous, few statistical data were presented to confirm or to refute these impressions.

All available cases of major operations on ligaments of the knee done in the author's private practice during the fifteen years 1938 to 1953 are now presented. Every effort has been made to include all cases. Although some must have escaped the net, no case has been knowingly overlooked. Eighty-two patients were reviewed for type of injury. Eighty of these had an adequate follow-up; these were used for the analysis of end results.

The exact type of operation used is of relatively little importance for the purposes of this report. One must assume that the same careful technique has been followed in the reconstruction operations as that which has been used in repair. The procedure of early repair has been described in detail in the previous report. To repair a typical injury, that is, the medial collateral ligament torn from the tibia, the anterior cruciate ligament torn from the tibia, and the medial meniscus torn, the following technique was used:

As stated in the previous article, access to the area is obtained through a long curved incision, beginning well above the femoral epicondyle anteromedially, and crossing the anteromedial aspect of the joint to end about three inches below the tibial rim along its anteromedial surface. This gives access to the entire medial aspect of the knee.

The superficial layer of the ligament is revealed and should be inspected from its

* Read at the Annual Meeting of The American Orthopaedic Association, Bretton Woods, New Hampshire, June 7, 1954.

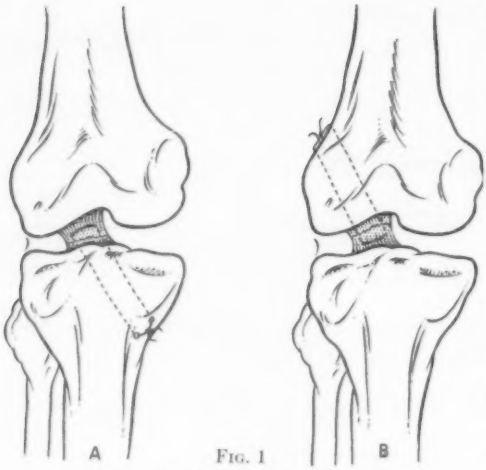

FIG. 1

Repair of anterior cruciate ligament.

A: Drill holes through tibia permit passage of suture to secure detached ligament to tibia.

B: Similar method to secure proximal end to the femur.

(Reprinted from *The Journal of Bone and Joint Surgery*, **32-A:** 725, Oct. 1950.)

attachment low on the tibia to above the knee. The site of the damage will be indicated by ecchymosis and hematoma within the fibers, usually at the tibial attachment. The tear is defined, by sharp dissection if necessary, and the superficial layer is retracted upward to expose the deep layer. This layer must be inspected entirely across the line of the joint from front to back, and rocking the tibia may give a clue as to the site of the tear. This tear is readily seen, if the operation is done before healing occurs. It is advisable at this stage to enter the knee joint by an incision through the capsule along the medial parapatellar line. Through this incision, the medial meniscus is exposed; decision as to its removal is made, and, if necessary, removal is carried out. The anterior cruciate ligament is inspected. If it has been torn from the tibia, two drill holes are passed from the anteromedial surface of the tibia into the area of the anterior spine (Fig. 1, *A*). A suitable ligature (No. 3 twisted silk or No. 10 cotton) is passed through one hole into the joint. It is recovered in the joint, is placed in a needle, and is woven through the loose end of the ligament. It is removed from the needle and is passed out of the knee through the second drill hole by means of a suitable ligature carrier. When this suture has been tightened, the ligament is snugged up into its bed. If the ligament is redundant, but has not been torn, it can be

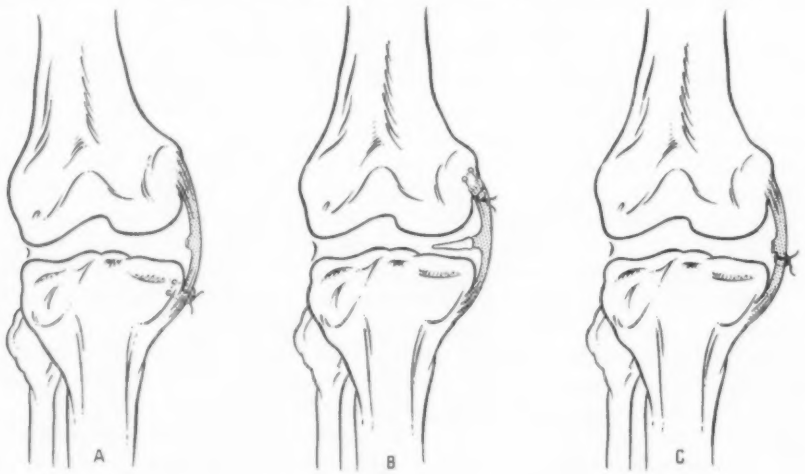

FIG. 2

Repair of deep layer of medial collateral ligament.

A: Repaired by suture to tibial margin through drill holes.

B: Repaired by suture to femoral condyle through drill holes.

C: Simple suture of torn ends of ligament.

(Reprinted from *The Journal of Bone and Joint Surgery*, **32-A:** 725, Oct. 1950.)

shortened by a similar procedure after some scarification. If the femoral attachment has been torn away, a similar repair is made with two drill holes (Fig. 1, *B*), in this instance passing from the lateral epicondylar ridge (through a small lateral incision) into the intercondylar notch or *vice versa*. After these sutures have been placed, they are not tied until the repair of the medial ligament has been completed, and the wounds are ready to be closed.

The immediate repair of the deep layer of the collateral ligament may be done by various methods. If there has been a direct tear in the ligament with two well defined margins, simple suture with imbrication, if feasible, will suffice (Fig. 2, *C*). If the ligament has been avulsed from the bone, the best method of repair consists in placing a series of three or four drill holes at the site of the attachment to bone, about three-quarters of an inch apart (Fig. 2, *A* and *B*). Suitable suture is passed through the ligament end, into one drill hole, out of an adjacent drill hole, and back through the ligament. When all of these have been placed, the knee is positioned at about 150 to 160 degrees, and all ligatures are tied. As a rule, the superficial layer can be repaired by simple suture to its bed. If not, a similar procedure may be carried out by drill holes at this level (Fig. 3). General imbrication of the ligament by suture should be done in order to obtain maximum tightness. For other types of injury similar procedures are used, a lateral incision for the injuries to the structures of the lateral side, and a posterior incision for the injuries to the posterior cruciate ligament. *Reconstruction* of the medial collateral ligament has been carried out by detaching the tibial attachment and re-attaching it further down the tibia, or by plication, or occasionally by fascial graft, depending upon the utilizable material remaining.

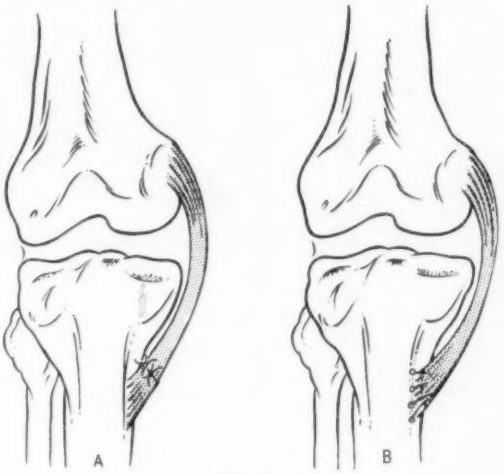

FIG. 3

Repair of superficial layer of medial collateral ligament.

A: Suture of torn end of ligament to stump.

B: Repair of avulsed end by suture through drill holes in tibia.

(Reprinted from *The Journal of Bone and Joint Surgery*, **32-A:** 726, Oct. 1950.)

The cruciate *reconstruction* has usually been done by using a six-inch or seven-inch strip of tendon three-quarters of an inch wide, beginning as rectus femoris tendon above the patella, extending along the medial side of the patella, and continuing by including a strip of the patellar tendon, down to its attachment to the patellar tubercle. This is passed through a large drill hole, five-sixteenths of an inch in diameter, running from the patellar tubercle into the area of the anterior spine of the tibia, then across the knee joint, and out through a drill hole extending from the back of the intercondylar notch to the lateral epicondylar rim (Campbell technique). Various other methods have been utilized, depending somewhat upon the circumstances.

It should be repeated that this report does not concern primarily the *type* of operation but rather the time of and the completeness of the repair.

The method of follow-up is of importance since there seems to be no good substitute for personal objective examination by the surgeon. Of the eighty patients available, the author was able to see forty-two (53 per cent.) for personal examination during a two-month period. Another nine patients (11 per cent.) had sufficiently detailed records to provide the necessary specific information sought. Twenty-nine patients (36 per cent.) responded by returning the questionnaire. Thus 89 per cent. have had a recent detailed analysis especially made for this report.

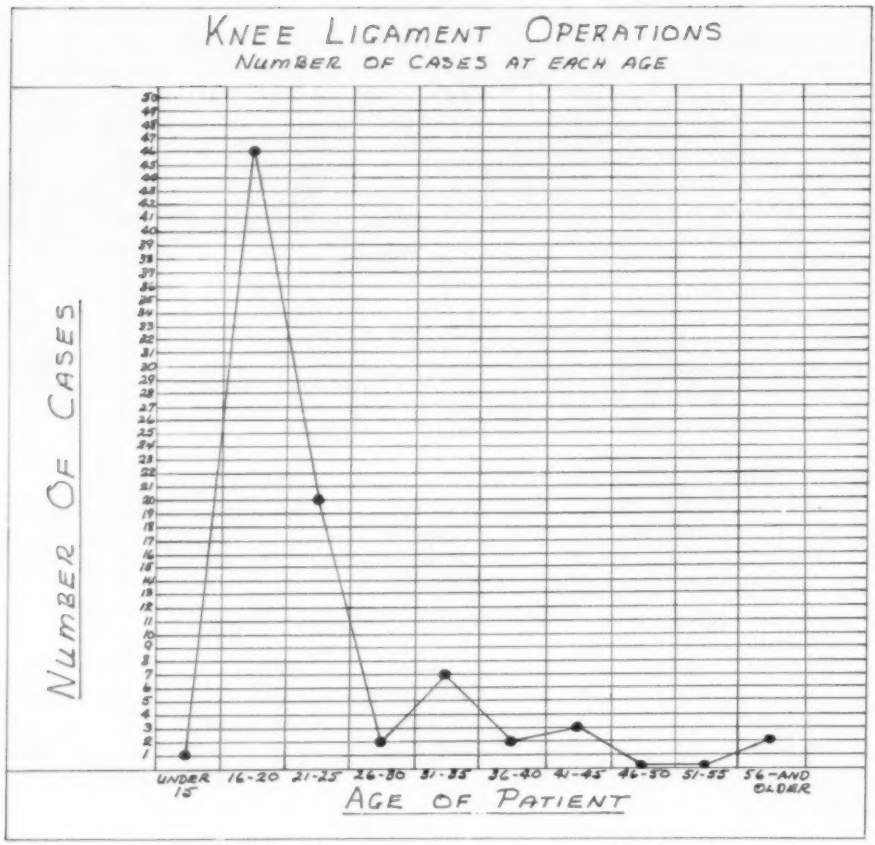

CHART I

The average follow-up period was three and one-third years, ranging from six months to fifteen years. Many of the patients with a short follow-up record had excellent results when last seen. Although I have heard that they continue to do well and to play football, their follow-up period has been listed as of the time of the last complete examination.

It is interesting to note that the number of operations done each year has steadily increased. Only an occasional operation was done prior to 1946, in which year three operations were done. With increasing confidence and with a better understanding of the indications for operation, the number of patients operated upon increased each year, to reach, in 1953, a total of eighteen. Most of the patients operated upon in 1953 are not included in this survey because of the short period of follow-up.

The age incidence at the time of injury presents some interesting aspects (Chart I). One would expect more cases of injury in the active years of life; this is confirmed by the fact that 80 per cent. of the patients were under twenty-five years of age. We were hardly prepared for the finding that 55 per cent. of the patients were under twenty years of age. This finding may be due to the fact that many youngsters grow rapidly and their bones mature early; their joints, however, remain relaxed, as is illustrated in one patient operated upon recently. The patient was a boy, seventeen years old, six feet three and one-half inches tall, weighing 215 pounds, with at least 15 degrees of lateral motion in the uninjured knee; he had the frame of a man with the joints of a seventeen-year-old.

TABLE I

TIME OF OPERATION

(Eighty Patients)

Early Under Two Weeks		Late Two Weeks to Three Months		Reconstruction Over Three Months	
(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)
44	55.	20	25.	16	20.

Only one patient was under fifteen years of age (a girl six years of age) and two were over forty-five years of age.

I am convinced that *early* repair is a *sine qua non* for consistently good results and I have, therefore, arbitrarily divided the patients in this series according to the time elapsed between the time of injury and the time of surgery. Believing that primary healing should occur in about two weeks and that scar retraction should be complete in three months, I have grouped the patients in three categories: *early*, comprising those operated upon within two weeks of the time of injury; *late*, those operated upon between two weeks and three months; and *reconstruction*, those operated upon three months after the injury (Table I). Minor variations would occur if the time periods were altered, but no significant change in the pattern would result. Just over one half of the patients are included in the *early* group (55 per cent.). All of the patients might well have been divided into two groups only, early repair and late repair—a division which would show even more dramatically the advantage of early repair.

TABLE II

TYPE OF INJURY

(Eighty-two Patients *)

	No. of Cases		Per cent.
Injury to:			
Structures of the medial side		69	84.
Medial collateral ligament, anterior cruciate ligament, and medial meniscus	24		
Medial collateral ligament and medial meniscus	16		
Anterior cruciate ligament and medial meniscus	17		
Total	57		70.
Medial collateral ligament	3		
Medial collateral ligament and anterior cruciate ligament	3		
Medial collateral ligament, anterior cruciate ligament, and both menisci	3		
Medial collateral ligament, both cruciate ligaments, and medial meniscus	3		
Structures of the lateral side		6	7.5
Lateral collateral ligament, anterior cruciate ligament, and lateral meniscus	2		
Lateral collateral ligament and anterior cruciate ligament	1		
Lateral collateral ligament and lateral meniscus	1		
Posterior cruciate ligament and lateral meniscus	1		
Lateral collateral ligament, both cruciate ligaments, and lateral meniscus	1		
Cruciate ligaments only		7	8.5
Anterior cruciate ligament	3		
Posterior cruciate ligament	3		
Both cruciate ligaments	1		
Note:			
Injuries to the cruciate ligaments combined with other injuries	55		
Injuries to the cruciate ligaments alone	7		
Total no. of cases with injuries to cruciate ligament		62	75.

* Two patients have been followed for too short a time to be included in the analysis of end results.

TABLE III

QUESTION A: DOES YOUR OPERATED KNEE BOTHER YOU?

	Early		Late		Reconstruction	
	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)
Athletes						
Yes	5		7		8	
No	23	82.	5	42.	7	46.
Others						
Yes	8		5			
No	8	50.	3	38.	1	
Total	44		20		16	
Yes	13		12		8	
No	31	71.	8	40.	8	50.

Classification of the patients according to the type of injury presented some difficulty, for so many different combinations of injuries to the ligaments are possible. That the majority of the patients fall into fairly consistent patterns is indicated by Table II. The most common pattern is that of some combination of injury to the medial collateral ligament, the medial meniscus, and the anterior cruciate ligament. Actually sixty-nine patients of eighty-two patients (84 per cent.) had injuries to the structures of the medial side; only six patients (7.5 per cent.) had injuries to structures of the lateral side; and seven patients (8.5 per cent.) had injuries to the cruciate ligaments alone.

Most significant is the fact that in sixty-two patients (75 per cent. of the eighty-two patients operated upon), one or both of the cruciate ligaments were torn, the anterior cruciate being torn in all but four patients in this group. This points out the fact that anterior-cruciate deficiency has been a primary factor in the indications for surgical repair.

A separate card containing all pertinent data has been filed for each patient. In addition, a questionnaire was drawn up on which answers to definite questions were recorded either by the examining physician or by the patient himself. Every patient completed the questionnaire. It is difficult to frame questions in such a way that the patient's mental slant may not tend to influence his judgment as to his physical condition. By specific questions an attempt was made to minimize this tendency and to obtain yes-or-no answers.

QUESTIONNAIRE

Question A: *Does your operated knee bother you?* As shown in Table III, 82 per cent. of the athletes operated upon early had no complaints, while only 50 per cent. of the non-athletes felt that their knee was in such good condition.

TABLE IV

QUESTION B: IS IT AS GOOD AS YOUR OPPOSITE KNEE?

	Early		Late		Reconstruction	
	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)
Athletes						
Yes	22	79.	4	33.	4	26.
No	6		8		11	
Others						
Yes	1	6.	2	25.		
No	15		6		1	
Total	44		20		16	
Yes	23	53.	6	30.	4	25.
No	21		14		12	

TABLE V

QUESTION C: ARE YOU COMPLETELY HAPPY WITH THE RESULT OF YOUR OPERATION?

	Early		Late		Reconstruction	
	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)
Athletes						
Yes	26	93.	9	75.	13	87.
No	2		3		2	
Others						
Yes	12	80.	6	75.	1	
No	3		2			
Total	43		20		16	
Yes	38	88.	15	75.	14	88.
No	5		5		2	

Question B: *Is it as good as your other knee?* This question repeats the same thought as Question A in a different way, with some difference in result. The athletes show essentially the same result, but the non-athletes show a considerable shift to the negative side: 79 per cent. of athletes in the *early* group thought their knee was at least as good, while 92 per cent. of non-athletes in this group did not (Table IV).

Question C: *Are you completely happy with the result of your operation?* Of all the questions, this one is probably of the least value statistically since answers to it may reflect loyalty to the surgeon, as well as satisfaction with the knee. Patients in the *late* and *reconstruction* groups had been told that the operation might fail. Many expressed themselves as satisfied when the actual result was indifferent or only fair. Even here, however, the emerging pattern is clear (Table V): The earlier the operation is done, the better the result.

Question D: *Has your knee kept you from participating in athletics?* The question was, of course, restricted to the fifty-four patients who were classified as athletes (Table VI). Such a classification was made only if the patient was a regular high-school, college, or professional athlete in regular competition as a member of the team. The question referred to his return to his particular sport, usually football, and to athletics in general,—that is, to unrestricted competition. A football player returning to basketball, but not to football, would answer "yes" to this question. In many ways, this is the most significant

TABLE VI

QUESTION D: HAS IT KEPT YOU FROM PARTICIPATING IN ATHLETICS?

	Early		Late		Reconstruction	
	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)	(*No. of Cases*)	(*Per cent.*)
Athletes	28		11		15	
Yes	3		4		9	
No	25	89.	7	64.	6	40.

table of all. It should be noted that 89 per cent. of the patients in the *early* group returned to active non-restricted athletics. Of the three who did not return, one had not had the anterior cruciate ligament repaired, although it had been torn, and in two repair of the cruciate ligament had failed. *All three athletes* who did not return to competition did not return because of *anterior-cruciate* instability.

Of the *late* group, seven of the eleven had had the cruciate ligament repaired; four (57 per cent.) of these returned to competition, all with a negative drawer sign. Three did not return, and all three have anterior-cruciate instability. Of the four patients without cruciate severence, three (75 per cent.) returned to competition; the fourth had generalized synovitis of the knee.

TABLE VII

GRADING OF ANSWERS TO TEN QUESTIONS UNDER QUESTION B

	Early	Late	Reconstruction	Total
No. of Cases	44	20	16	80
Grade (average)	87	77	70	

TABLE VIII

GRADING OF ANSWERS TO TEN QUESTIONS UNDER QUESTION B

(Eighteen patients with injury to the medial collateral ligament and medial meniscus)

	Early		Late		Reconstruction	
	(*No. of Cases*)	(*Grade*)	(*No. of Cases*)	(*Grade*)	(*No. of Cases*)	(*Grade*)
Athletes	8	97 (average)	2	97 (average)	3	100 (average)
Others	2	75 (average)	3	72 (average)		
Total	10	93 (average)	5	82 (average)	3	100 (average)

In the *reconstruction* group, of the six (40 per cent.) who can play, three had had no cruciate damage, the fourth had had an incomplete tear of anterior cruciate ligament, the fifth had had the posterior cruciate ligament avulsed from the tibia, and the sixth had had the anterior cruciate ligament avulsed from the femur. Not one of this group who returned to competition had had a complete tear through the substance of a cruciate ligament. Of the nine in the *reconstruction* group who did not return to competition, *all had cruciate-ligament instability* as the major cause of their disability. Only three of the *reconstruction* group did not have injury to the cruciate ligament; all three gained normal function following successful reconstruction of the medial collateral ligament.

Sixteen athletes of the fifty-four (30 per cent.) did not return to competition (only three of these were in the *early* group); *fifteen* (94 per cent.) *of these had cruciate instability.*

In the questionnaire, Question B, *Is it as good as your opposite knee?*, includes ten sub-questions to be answered if the answer to the main question is "No". These are:

1. Does it hurt?
2. Is it loose or wobbly?
3. Is knee motion restricted?
4. Does it swell?
5. Does it seem weak?
6. Does it catch or snap?
7. Does it bother you to squat?
8. Do you have trouble with stairs?
9. Does it limit your activities? How?
10. Does it handicap you in your work?

Each of these questions is valued at ten points; perfect score is 100 points. Tables VII through XIII are based on the answers to these ten questions. The grade given in answer to these questions is used for the purposes of comparison only; it does not represent a percentage estimate of the success of the result. Obviously, the questions are not of equal value and many overlap,—that is, numbers 8 and 9, numbers 7 and 10, and numbers 2 and 5. They were chosen in order to ferret out the exact reason the knee was not as good as its mate.

The general pattern is clearly shown in Table VII. *The earlier the treatment is begun, the better the result.* This pattern is consistent throughout by every means of comparison, with the possible exception of the material presented in Table VIII. In the group of patients with injuries to the medial collateral ligament and the medial meniscus, in whom the cruciate ligaments had not been damaged, good results were obtained regardless of the time of surgery. Even in this group the *early* repairs were definitely better than the *late* repairs.

TABLE IX

GRADING OF ANSWERS TO TEN QUESTIONS UNDER QUESTION B

(Twenty-three patients with injuries to cruciate ligaments and medial meniscus)

	Early		Late		Reconstruction	
	(*No. of Cases*)	(*Grade*)	(*No. of Cases*)	(*Grade*)	(*No. of Cases*)	(*Grade*)
Athletes	5	88 (average)	4	82 (average)	8	70 (average)
Others	1	80 (average)	4	80 (average)	1	70 (average)
Total	6	87 (average)	8	81 (average)	9	70 (average)

The *reconstruction* group here consisted of three athletes who gained splendid results, but the group seems to be too small and too "loaded" to be statistically sound (Table VIII). Technically, the reconstruction of the medial collateral ligament was done by detaching the ligament from the tibia and re-attaching it lower down.

Table IX seems self-explanatory; it follows the familiar pattern. The chief complaint in these twenty-three patients was cruciate instability. This should definitely indicate that, to these people at least, function of the cruciate ligament seemed essential! All of the patients in the *late* and *reconstruction* groups had had extensive quadriceps rehabilitation before operation was recommended.

In Table X, all patients with laceration of a cruciate ligament are included regardless of whatever other injury existed. Here the importance of early repair is particularly noticeable. With damage to a cruciate ligament, early repair is essential if good results are to be obtained. It should be noted that in 25 per cent. of the patients in the *early* group, cruciate-ligament damage was not diagnosed before anaesthesia was given. We cannot safely use a negative drawer sign as an excuse for procrastination!

Of the patients in the *early* group with cruciate injuries, twenty-five were athletes; twenty-two returned to regular competition, three did not. In each of these three, the cruciate ligament either was not repaired or the repair had failed.

Of those in the *late* group, seven patients were athletes; four of these returned to competition, each with a negative drawer sign. Three of these did not return to regular competition, and in each there was a positive drawer sign.

Of the patients in the *reconstruction* group, only one returned to championship football, while three played some football. This emphasizes again the vital importance of *early* operation in the treatment of cruciate-ligament injuries.

The question of relationship between the severity of injury and the success of repair has been raised and is, of course, important. Table XI presents the results in twenty-four patients with a similar serious injury,—a complete severence of the medial collateral ligament and the anterior cruciate ligament, with rupture of the medial meniscus. Highly satisfactory results were obtained if the injury was brought to operation early; poor results were the rule if surgical treatment was delayed. *The more serious the injury is, the more important early repair becomes.*

Out of this series of eighty, there were seven instances when the cruciate ligament

TABLE X

GRADING OF ANSWERS TO TEN QUESTIONS UNDER QUESTION B

(Fifty-seven patients with injury to the cruciate ligaments *, either alone or in combination)

Early		Late		Reconstruction	
(*No. of Cases*)	(*Grade*)	(*No. of Cases*)	(*Grade*)	(*No. of Cases*)	(*Grade*)
34	87 (average)	12	73 (average)	11	65 (average)

* Fifteen cases (25 per cent.) of injury to the cruciate ligaments were undiagnosed before anaesthetic was given.

TABLE XI

GRADING OF ANSWERS TO TEN QUESTIONS UNDER QUESTION B

(Twenty-four patients with injuries to the medial collateral ligament, the anterior cruciate ligament, and the medial meniscus *)

	Early		Late		Reconstruction	
	(*No. of Cases*)	(*Grade*)	(*No. of Cases*)	(*Grade*)	(*No. of Cases*)	(*Grade*)
Athletes	11	95 (average)	2	63 (average)	3	53 (average)
Others	7	82 (average)	1	40 (average)		
Total	18	90 (average)	3	58 (average)	3	53 (average)

* Termed the "unhappy triad" by the author. This major injury is readily diagnosed; this accounts for the large number of patients in the early group.

was not repaired although damage was recognized. Five of these patients had definite instability and disability following operation. Two did not; both of these had incomplete tears.

In five of the patients the damage was not repaired for the following reasons: "too difficult" (in one patient with injury to the posterior cruciate), "could be done later" (one), "failed to heal well" (one), and "irreparable because of loss of substance of the ligament" (two).

The question has been raised whether or not, with such outstanding results in athletes, we should confine the repair to this group. In Table XII is given a comparison of the results in the athlete and non-athlete. The greatest difference seems to be in the *early* group. This reflects the rehabilitation drive of the athlete. The athletes work much better

TABLE XII

GRADING OF ANSWERS TO TEN QUESTIONS UNDER QUESTION B

(Comparison of grades for athletes with those of non-athletes)

	Early	Late	Reconstruction	Total
Athletes				
No. of Cases	28	11	14	53
Grade	93 (average)	78 (average)	71 (average)	84 (average)
Non-Athletes				
No. of Cases	15	9	2	26
Grade	76 (average)	75 (average)	65 (average)	75 (average)
Total				
No. of Cases	44	20	16	80
Grade	87 (average)	77 (average)	70 (average)	80 (average)

TABLE XIII

GRADING OF ANSWERS TO TEN QUESTIONS UNDER QUESTION B

(Comparison by Age Groups)

	Early	Late	Reconstruction	Total
Under 20 years				
No. of Cases	21	12	12	45
Grade	89 (average)	75 (average)	66 (average)	79 (average)
Over 20 years				
No. of Cases	23	8	4	35
Grade	84 (average)	78 (average)	60 (average)	80 (average)
Athletes				
No. of Cases	28	11	14	53
Grade	93 (average)	78 (average)	71 (average)	84 (average)

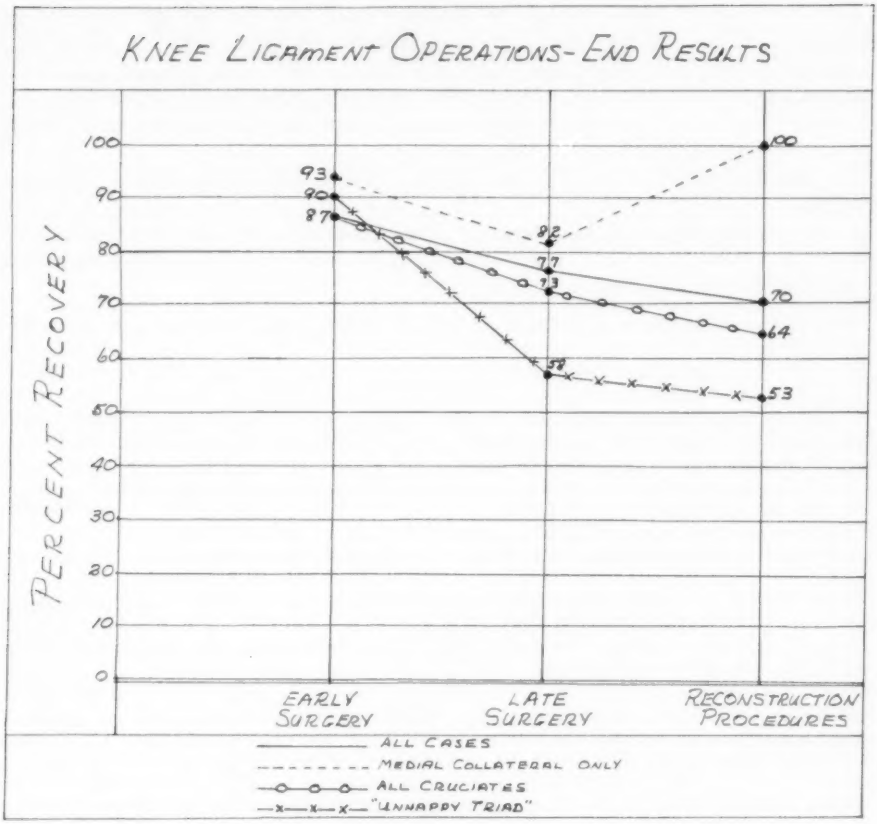

CHART II

and take advantage of enlightened training programs. It is the author's opinion that injuries in non-athletes should be repaired and that a greater effort should be made to duplicate the rehabilitation carried out in the more active patients.

The assumption, that the athletes do better simply because of age is refuted by Table XIII. In this series the patients are pretty evenly divided into two groups—those under and those over twenty years of age. Surprisingly little difference occurs between the two age groups. The results in those under twenty are a shade better. The results in the athletes are better than those in either age group.

An attempt is made to summarize the end results in Chart II. The significant fact is the uniform grouping of the patients in the *early* group at a consistently higher level of recovery. The number of good results in all cases with cruciate injury rapidly diminishes as the time between injury and surgery increases. The severity of the injury is relatively unimportant if the injury is repaired early.

CONCLUSIONS

1. Cruciate-ligament instability at the knee causes a definite disability and should be prevented if possible.

2. Repair of the cruciate ligaments is surgically feasible and highly successful if it is done early.

3. Cruciate-ligament instability was the primary cause of disability in those athletes

who did not return to competition. Of the sixteen athletes who did not return to full competition, fifteen (94 per cent.) gave cruciate-ligament instability as a major cause of their failure to participate. They could tolerate some pain, some stiffness, some weakness, some lateral instability, but they could not tolerate cruciate instability.

4. The time of the repair is vastly more important than the severity of the injury, but the more serious the injury is, the more urgent is *early* repair.

5. Results in the athletes were markedly better than those in non-athletes, regardless of age.

6. Complete rupture of any ligament of the knee demands early surgical repair to assure best results. In all types of injury *early* repair (under two weeks) gives much better results than *late* repair or *reconstruction*.

1. O'Donoghue, D. H.: Surgical Treatment of Fresh Injuries to the Major Ligaments of the Knee. J. Bone and Joint Surg., **32-A:** 721–738, Oct. 1950.

DISCUSSION

Dr. George E. Bennett, Baltimore, Maryland: In this type of surgery there are four "musts" which I consider essential in order to obtain such successful results as Dr. O'Donoghue has:

1. The patient must be seen early (unfortunately, my patients don't come to me that early);
2. The surgeon must be a good diagnostician and must be able to identify these injuries;
3. The surgeon must have good judgment;
4. The surgeon must be competent.

I doubt if anyone will question the fact that the operations should be done in a hospital where there are good facilities.

I disagree with Dr. O'Donoghue concerning reconstructive surgery of old knee injuries. We have all been led to believe that a torn anterior cruciate ligament means that a person is completely unable to participate in athletics. In 1922, a Princeton soccer player came to Baltimore with a locked knee. I thought he had a torn meniscus. I explored his knee joint and found that he had a torn anterior cruciate ligament which was locking his knee. Today, I would probably attempt the operation which Dr. O'Donoghue has described. At that time, I did my first reconstruction of a medial collateral ligament by removing the frayed cruciate ligament and by performing an overlapping plication of the fascia and ligamentous tissue which ran parallel with the anterior cruciate. That patient made the All-American Soccer Team the next year; in the following year he was captain of the All-American Soccer Team.

Later, I began adding to this overlapping technique a reinforcement of the inner border of the knee joint with fascia. This was done only in patients with slightly relaxed knees. I do believe that, if the injury is seen early, the operation Dr. O'Donoghue has described should be done. The results should be admirable. However, if the injury is not seen early, the case is not hopeless.

I think that of the patients with injured menisci whom I see and have to operate upon, 25 per cent. have a relaxed knee associated with the injury. The simple removal of the meniscus will not cure the condition. Some type of reconstruction of the medial collateral ligament, such as plication, reinforcement with fascia, or some other plastic procedure, must be done.

Dr. J. S. Speed, Memphis, Tennessee: Dr. O'Donoghue's concept of the proper treatment of injuries to ligaments of the knee joint is unquestionably sound. The importance of early repair and of the surgical techniques described for these repairs, both in his original presentation in 1950 and in the follow-up study, are an important contribution to orthopaedic surgery.

The well documented statistical data depicting the results in the follow-up study of this large series is both instructive and convincing.

I am in full accord with Dr. O'Donoghue in regard to the early exploration and repair of the severe injuries to the ligaments and cartilage of the knee. Procrastination can only complicate, or preclude, adequate repair and vitiate the end results. There are, however, some ligament and cartilage injuries which recover spontaneously with normal function, particularly in those not engaged in athletics. It would seem reasonable to assume that something has been torn in every knee-joint injury which is accompanied by hemarthrosis and in which the roentgenogram does not demonstrate a fracture. Such injuries might be small separations of the lateral attachments of the menisci or a mild shredding type of tear in the collateral ligaments, or both. These do not require surgical exploration.

Just where the line of demarcation is to be drawn between these injuries and the typical severe football injury must rest largely on the experience and diagnostic acumen of the individual surgeon. For the uninitiated, it is better to err on the side of conservatism; for a surgeon skilled in the diagnosis and technique of surgical repair, it is better to err on the side of immediate surgical exploration.

The importance of early, preferably immediate, examination of knee injuries by the operating surgeon cannot be overemphasized. A better estimate of the extent of the injury can be made then than at any other time, except after surgical visualization. If necessary an anaesthetic of short duration is justifiable for diagnostic purposes immediately after the injury, if pain and muscle spasm preclude a satisfactory examination. Examination under anaesthesia is usually desirable after swelling and muscle spasm have become established. This can be postponed until the time of the contemplated operation if surgical repair of the injury appears to be necessary.

There is little controversy regarding repair of the medial or lateral collateral ligaments and the anterior cruciate ligament for definite instability in the acute stage. Reversal of the Mauck operation for laxity of the medial collateral ligament in the reconstructive period has, in our experience, proved most satisfactory. The attachment of the ligament to the femoral epicondyle is transplanted upward after the thorough freeing of all of its femoral attachments.

In spite of Dr. O'Donoghue's convincing arguments to the contrary, there is still a wide difference of opinion as to the advisability of repairing or reconstructing the anterior cruciate ligament in late cases. Anatomical, technical, and functional evidence negating the necessity for the operation have been published and will not be repeated here.

In our experience, repair of the remaining portions of the anterior cruciate in the subacute or reconstruction period is difficult or impossible. Construction of a new cruciate ligament, by whatever method one prefers, is definitely helpful and is indicated when excessive anterior-posterior instability is present. Reconstruction of the medial or lateral collateral ligament is also necessary in most cases. We do not reconstruct the anterior or posterior cruciate ligament in cases of mild instability. For practical purposes, we divide the patients in the reconstruction period into three groups depending on what abnormalities are found at operation.

1. A tear of the medial or lateral meniscus, or of both, no collateral-ligament instability, rupture of the anterior cruciate ligament, and mild anterior-posterior instability are repaired by the removal of the torn meniscus only. This condition is often found unexpectedly at operation.

2. A tear of the medial meniscus, definite instability of the medial collateral ligament, rupture of anterior cruciate ligament, with slight or moderate anterior-posterior instability, are repaired by the removal of the medial meniscus and repair of the medial collateral ligament.

3. A tear of the meniscus, gross instability, both medial and anterior-posterior, and rotation, with laxity of the medial collateral ligament and rupture of the anterior cruciate ligament, are repaired by removal of the torn meniscus, reconstruction of the anterior cruciate ligament, and repair of the medial collateral ligament.

A follow-up study of those in whom we have performed a reconstruction of the anterior cruciate ligament has shown that the majority have a persistent, slight or moderate, anterior-posterior instability. It is for this reason that we do not recommend reconstruction of the anterior cruciate in those with only minor instability.

Dr. O'Donoghue has been a courageous pioneer in this interesting field of surgery. His work is outstanding, and I am sure that it will greatly decrease the chronic crippling results which have been so frequent following injuries to the ligaments of the knee.

DR. O'DONOGHUE (*closing*). The last discussor called my attention to something which I should have emphasized. I certainly did not mean to imply that one should wait two weeks before doing surgical repair. On the contrary, I think that two weeks is getting toward the wrong end of the scale. Once surgical treatment has been elected, the sooner it is done the better. If one can operate within two or three hours after injury, it is much more simple than it would be the next day because the knee soon swells and the tissues become more difficult to handle. It is similar to the treatment of a compound fracture when normal tissue to deal with makes surgery much easier.

I appreciate very much Dr. Bennett's discussion. His work caused me to realize that good results can be obtained in grossly injured knees. It is difficult to see these injuries early. It takes a good deal of cooperation between the trainer and the doctor who is to care for the injured athletes to enable the physician to see the injury before it becomes so disabling that the trainer has given up and has sent the athlete in for something definitive to be done. I think reconstruction is extremely difficult work. Dr. Bennett has had some very brilliant results. I have read his articles concerning reconstruction and I know the brilliant surgery he performs. We cannot all get such good results in most cases, but I think any competent orthopaedic surgeon can get these good results in an acute injury if he operates meticulously and thoroughly. I want particularly to emphasize that it is much easier to do repair than it is to do reconstruction. Dr. Speed also emphasized that early repair is very much easier than late repair. It is important to diagnose the condition accurately; we certainly do not operate upon a very high percentage of the injuries to the ligaments which we see. We operate only if we are convinced that one of the major ligaments has been completely torn; an incomplete tear heals well without retraction and an essentially normal knee results. I agree entirely with Dr. Speed concerning his remarks on reconstruction. Certainly, a surgeon is not justified in doing an extensive

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SOFT-TISSUE TUMORS OF THE SOLE

With Special Reference to Plantar Fibromatosis *

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Although Dupuytren, in his classic account of palmar fibromatosis, mentioned cases in which involvement of the plantar fascia was present, plantar fibromatosis has received scant attention in the 120 years which have passed since, as compared to that accorded this condition in the hand.

In contrast to the palmar lesions, which long have been regarded justly as benign, knowledge of the natural history of the lesion in the foot, to judge from the literature and from medical records, is vague. At times the lesion is regarded with suspicion; occasionally, it is believed to be frankly malignant.

Because the behavior of these lesions in the foot is poorly understood, we decided to review the records, in the files of the Mayo Clinic, of all soft-tissue tumors, both benign and malignant, involving the sole of the foot. We found sixty-nine cases of plantar fibromatosis and nine cases of malignant neoplasms of the soft tissues of the sole; these cases form the basis of this report.

REVIEW OF THE LITERATURE

Pickren and his coworkers, in 1951, reported a series of sixteen cases of plantar fibromatosis and were able to find reports of 104 cases in the literature. In addition to the cases included in their review, the authors have been able to find accounts of the following twenty-eight cases:

Meyerding and Shellito, in 1948, reported a series of twenty-four cases of plantar fibromatosis among 882 cases (2.7 per cent.) of Dupuytren's contracture seen at the Mayo Clinic over a twenty-year period. In the same year, Hammond and Dotter reported on a forty-year-old man who had bilateral involvement of both the feet and the hands.

Kapiloff and Prior, in 1952, reported two cases of plantar fibromatosis in children. One was an eight-year-old Negro boy in whom a tumor developed in the sole after an injury. The lesion was excised; in the succeeding sixteen months, three additional surgical excisions were performed for the persistently recurring lesion.

Keasbey, in 1953, reported four cases of fibrous tumors in the palmar and plantar fascia occurring in children. Three lesions were located in the palm and one in the sole. From the information given, we are of the opinion that these were cases of Dupuytren's contracture.

Pathology

The literature contains a number of brief descriptions of the pathological changes in Dupuytren's contracture in the hands and in the feet; however, no studies were devoted primarily to the pathological aspects of the lesion.

* Abridgment of thesis submitted by Dr. Allen to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science in Pathology.

† The Mayo Foundation is a part of the Graduate School of the University of Minnesota.

Langhans, in 1887, described the essential pathological features of this lesion in specimens removed from the hand. He noted the areas of increased cellularity which characterize the lesion and expressed the opinion that the earliest change was increased vascularity with proliferation of perivascular fibrous tissue. In 1897, Ledderhose observed the same changes in Dupuytren's contracture involving the plantar fascia. Janssen gave an excellent description of the pathological anatomy and was probably the first to call attention to the fact that the histological appearance of actively proliferating areas may bear a strong resemblance to that in sarcoma. Janssen considered that the disease process was one of spotty hyperplasia. Iklé likewise was of the opinion that the condition was one of chronic hyperplasia, although he noted inflammatory features.

In 1941, Meyerding and his associates reported in detail the pathological findings in Dupuytren's contracture of the hands. They believed that the condition was best explained on the basis of chronic inflammation. Clay stressed the histological resemblance of the lesion to fibromata seen elsewhere in the body, especially desmoid tumors. Pickren and his coworkers stated that the histological picture observed in some cases of plantar fibromatosis could be interpreted as fibrosarcoma if it were found in other parts of the body, but that the process in the foot was clinically benign.

Relation of Plantar Fibromatosis to Fibromatosis Found Elsewhere

Kanavel and his associates found plantar involvement in two of twenty-nine cases of Dupuytren's contracture of the hand. In one case there was involvement of the thin fascial band which extends from the thumb to the index finger above and parallel to the web. The lesions in one other of their twenty-nine cases were noted on the dorsa of the fingers.

In a report concerning 361 epileptic patients (190 males and 171 females), Lund studied the occurrence of Dupuytren's contracture of the hands and of the feet, knuckle pads, "periarthrosis humeri", and Peyronie's disease. As a control group, he studied 1,021 brewery workers. He noted an incidence of Dupuytren's contracture of the hands at least four times greater in the epileptic patients than in the controls. Of the 361 epileptic patients, 50 per cent. of the males and 32 per cent. of the females had Dupuytren's contracture of the hands. Plantar fibromatosis was found in twenty-five of the 361 patients. These twenty-five patients consisted of twelve females and thirteen males. Plantar fibromatosis was noted in one of the controls. Of the 361 epileptic patients, twelve had "periarthrosis humeri". One hundred patients of each sex among the epileptics were examined for knuckle pads; this condition was found in twenty-nine males and thirteen females. Peyronie's disease was found in three of the 100 male epileptic patients examined for it.

Knuckle pads were present in twenty-two of Skoog's fifty patients who had Dupuytren's contracture of the hands. None of his patients had Peyronie's disease or keloids. Forty-three of these fifty patients who had palmar fibromatosis were examined for plantar involvement; ten patients, all of whom were men, had such lesions in the foot. He found knuckle pads in 35 per cent. of eighty-six epileptic patients who had Dupuytren's contracture of the hands and in 20 per cent. of 121 epileptics who did not have Dupuytren's contracture. Of 207 male epileptics, seven had Peyronie's disease; four of these had palmar fibromatosis, and one had involvement of both the palmar and plantar aponeurosis.

In a study of an unstated number of cases of Dupuytren's contracture of the hands, Bunnell found nine in which plantar lesions were also present. He encountered also eight instances of Peyronie's disease and five cases in which knuckle pads were noted. In one case a tight fibrous subcutaneous band extended down the front of the shoulder and the arm.

One instance of Peyronie's disease was found in the reports of the 104 cases of plantar fibromatosis by Pickren and his associates. Keloids were not noted in this group. In their

own series of sixteen patients, three had keloidal tendencies. None of the six males in this group had Peyronie's disease.

Meyerding and Shellito found associated palmar lesions in twelve of their twenty-four cases of Dupuytren's contracture of the foot.

Etiology

The number of factors which have been indicted singly or in combination as etiological possibilities in Dupuytren's contracture is truly varied and impressive. Skoog, in his review of the literature, listed the following general categories: (1) trauma; (2) neuropathy; (3) gout and rheumatism; (4) endocrinopathy; (5) faulty development; (6) contraction of the palmaris longus; (7) local infection; (8) tuberculosis; (9) chronic intoxication (chiefly lead poisoning); and (10) miscellaneous.

MATERIALS AND METHODS

As already indicated, a search of the files of the Mayo Clinic from 1907 through 1952 yielded sixty-nine instances of plantar fibromatosis and nine instances of malignant neoplasms involving the soft tissues of the sole of the foot.

Of the sixty-nine patients in whom diagnoses of plantar fibromatosis were made, thirty-five had had resective operations on the foot for this lesion. Of these, six patients also had had resection of palmar lesions. Pathological specimens were available from all these patients.

In two of the sixty-nine cases, specimens were taken at necropsy. In one of these, both the feet and the hands were involved and tissue was taken from both the palmar and plantar fascia. In the second case there was involvement of the left plantar fascia, with associated Peyronie's disease; tissue was taken from both sites.

Both plantar and palmar fascia was involved in nine of the sixty-nine cases, but resective surgery had been performed only on the hands; in four of these cases tissue was available for study.

In a total of twenty-nine cases in our study, specimens were available only from the involved plantar fascia; in seven cases specimens were available from both the feet and the hands, and in one case tissue was available from the foot and from the penis. In four cases specimens were available only from the hands. Thus, pathological specimens were available from the foot in thirty-seven of the sixty-nine cases of plantar fibromatosis, whereas specimens were available from the hand alone in an additional four cases.

In the thirty-two cases in which pathological material was not available from the feet, involvement of one or both hands was present. These cases are included on the basis of the clinical findings.

Surgical specimens were available in all nine cases of malignant tumors involving the sole.

The clinical records in each of the total of seventy-eight cases were abstracted, and follow-up letters were sent in all instances.

PLANTAR FIBROMATOSIS

Gross Pathology

The available specimens consisted of the excised portions of plantar fascia with attached fibrous tissue, fat, and, rarely, overlying skin. In nearly every specimen the plantar fascia was thickened by formation of a lobulated firm, irregular mass. The thickened zones consisted of multiple small nodules which merged with each other and with the fascial bundles (Figs. 1-A and 1-B). The individual nodules usually measured two to four millimeters in diameter but were occasionally larger; the largest discrete nodule was eight millimeters in diameter.

Fig. 1-A: Drawing showing the tumors in the arch of the foot and the clinical appearance of Dupuytren's contracture. (Reproduced with permission from: Dupuytren's Contracture of the Foot, by Henry Meyerding and J. G. Shellito. *Journal of the International College of Surgeons*, **11**: 596, 1948.)

Fig. 1-B: Exposure of the plantar fascia, demonstrating multiple nodules and thickening in Dupuytren's contracture. (Reproduced with permission from: Dupuytren's Contracture of the Foot, by Henry Meyerding and J. G. Shellito. *Journal of the International College of Surgeons*, **11**: 596, 1948.)

Fig. 1-C: The excised plantar fascia, showing an irregular tumor in the mid-portion of the specimen (actual size).

FIG. 1-A FIG. 1-B

A single specimen sometimes contained several thickened areas, each of which was composed of small nodules.

On cut section the tumor sometimes consisted of gray fibrous tissue within which fine bands and whorls could be seen. In other instances, the nodular portions consisted of sharply circumscribed zones of dull grayish-yellow tissue which contrasted rather sharply with the normal silvery, glistening bundles of fibrous tissue of the plantar fascia. When the fascia was sectioned parallel to the axis of its fibers, the glistening bundles of fibrous tissue could be followed to the affected portion. At this point the fascial fibers became distorted and compressed; sometimes they were interrupted by the nodules of tumor.

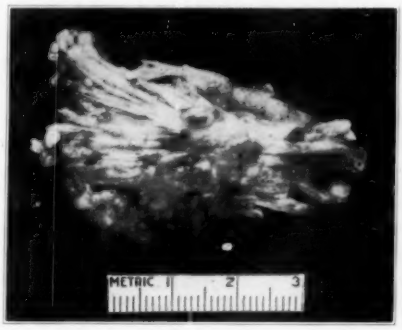

FIG. 1-C

The lesion was located in the longitudinal arch in thirty-eight of the forty-two cases in which the portion of plantar fascia involved was recorded. In two cases the nodules were located in the plantar fascia at the bases of the toes, along the heads of the metatarsals. In one case a nodule was located under the head of the third metatarsal bilaterally; involvement of the medial border of the left foot also was present. The lesion in one case appeared between the heads of the fourth and fifth metatarsals and presented on the dorsum of the foot, as well as on the plantar surface. With this single exception, all other lesions presented on the plantar surface of the foot.

The average size of the nodular, thickened areas was about 3 by 2 by 2 centimeters. The smallest excised mass measured 0.5 centimeter; the largest, 9 by 3 by 1.5 centimeters.

In most instances the growth presented clinically as a single nodule in the foot, in contradistinction to the multiplicity of nodules usually present in the hands. In seven

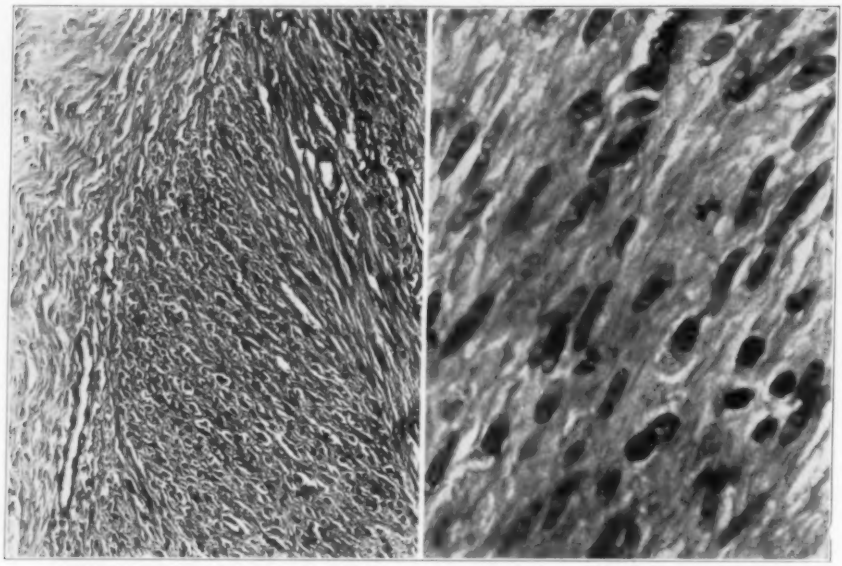

FIG. 2-A FIG. 2-B

Fig. 2-A: Photomicrograph (× 175; hematoxylin and eosin stain) showing proliferative nodule of average cellularity blending with normal fascia on the left.

Fig. 2-B: Photomicrograph (× 525; hematoxylin and eosin stain) showing the characteristic appearance of proliferating cells. Two mitotic figures are present.

cases, however, multiple nodules were present in one or both feet before surgical extirpation. An interesting finding in seven additional cases after excision of a single nodule was recurrence in the form of multiple tumors, usually in the region of the scar. Because of the irregular nodularity of the growth, it was not always possible to determine the limits of a single tumor. Moreover, it was easy to see how separate nodules coalesced to form a single mass.

The process did not tend to involve adjacent structures. In a single case the growth appeared to have developed within the substance of the tendon of the flexor hallucis longus. In two cases, in which previous operations had been performed, the masses were densely adherent to the skin and to the underlying muscles, nerves, blood vessels, and ligamentous structures. We did not find gross primary invasion into the muscles and deep structures of the foot, although occasionally the growth extended beyond the fascia into the adjacent fat and fibrous tissue. In some cases the skin was adherent to the underlying tumor.

Histopathology

The microscopic appearance of the lesion is so distinctive as to be diagnostic. The nodules seen grossly consisted of islands of proliferating fibroblasts which contrasted sharply with the relatively acellular collagenous aponeurotic background. In every instance examination under low magnification revealed a characteristic nodular, multicentric pattern of growth. Sometimes these proliferating foci were sharply separated from the adjacent compressed fascial bundles, which formed a pseudocapsule. Occasionally the nodules were discrete but blended gradually with the surrounding bundles, which were not compressed (Fig. 2-A).

Under higher magnification the cellular areas were seen to be composed of fibroblasts, with elongated fusiform or sometimes oval nuclei containing scant, finely vesiculated chromatin material, with one or two pale pink, small nucleoli (Fig. 2-B).

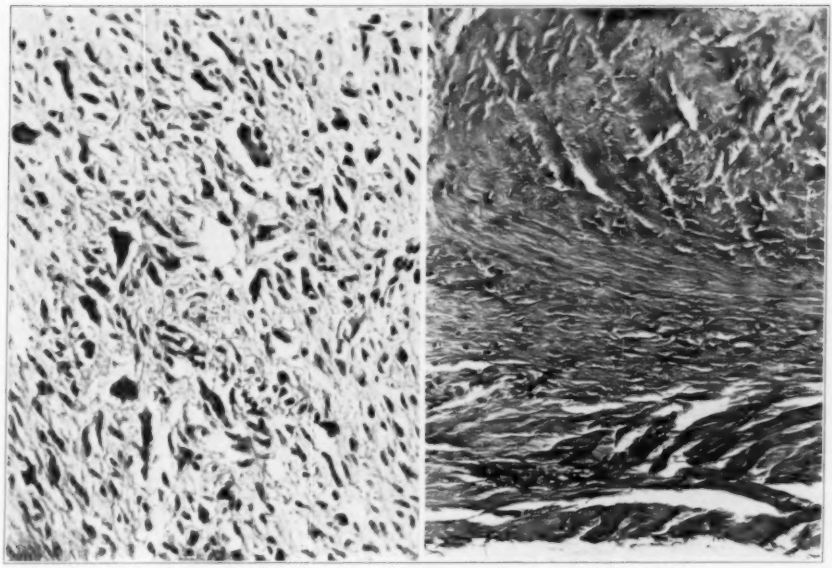

FIG. 2-C FIG. 2-D

Fig. 2-C: Photomicrograph (× 220; hematoxylin and eosin stain) showing a proliferating nodule with multinucleated cells and moderate variation in size and shape of cells.

Fig. 2-D: Photomicrograph (× 150; hematoxylin and eosin stain) showing the late stage of the disease. The proliferative nodule at the top is relatively acellular and is composed of dense collagen.

Collagen was present in the actively growing foci in every specimen; quantitatively, it usually was in an inverse ratio to the degree of cellularity. The collagen consisted typically of a loose network of fine fibers parallel to the axis of the proliferating cells. Variations in this appearance will be described later.

The proliferating fibroblasts generally varied little in size, shape, or staining reaction. However, the lesions in four of our cases were exceptions to this general rule, in that considerable variation occurred in these cytological features and multinucleated giant cells were fairly numerous (Fig. 2-C). These giant cells appeared to result from fusion of growing cells and the individual nuclei did not appear disproportionately large.

In most cases rare mitotic figures could be found after prolonged search. In the four cases mentioned, in which cellular variation was noted, mitosis was rather common; in one case, nearly every high-power field revealed two or three mitotic figures (Fig. 2-B).

In general, the nodules were highly cellular as compared to normal fascia (Fig. 2-A). In nearly every case we were able to find nodules ranging from highly cellular ones to some which were relatively acellular and composed mainly of dense and sometimes hyalinized collagen (Fig. 2-D). In these latter zones the collagen had lost its fine fibrillar structure and was easily distinguished from the normal fascial bundles, between which it was interposed. One lesion consisted entirely of dense hyalinized nodular tissue interposed between the fascial bundles. We were unable to correlate the presence of such areas with either the duration of the lesion or the age of the patient.

A nearly constant finding in our material was the peculiar relationship of the growing centers to blood vessels. Within the proliferative nodules themselves the blood vessels sometimes showed large hobnail-like endothelial cells which often appeared stratified. Often the shape of the lumen was irregular and slitlike because of invagination of proliferating tissue. More remarkable was the fact that plump fibroblastic cells surrounded the vessel and formed a cuff which was from two to eight layers of cells in thickness (Fig. 3). At times

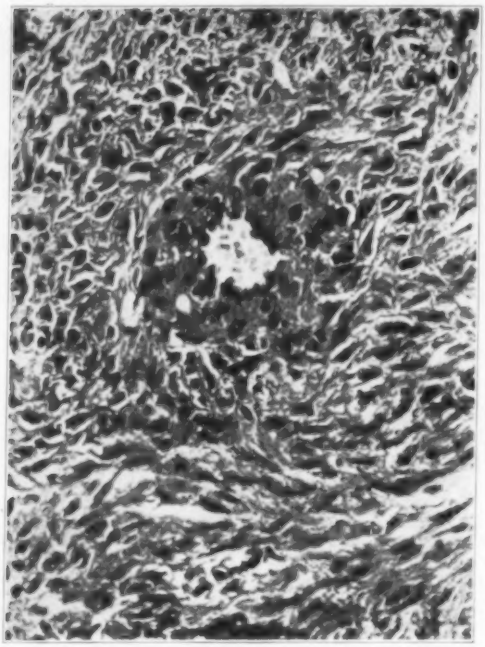

FIG. 3

Photomicrograph (× 330; hematoxylin and eosin stain) demonstrating the vessel within a proliferative nodule. The wall consists of a thick cuff of proliferating fibroblasts.

this feature formed a striking picture. In other cases only a few such vessels were observed. It was, however, a fairly constant and distinctive finding. Even more unusual, however, was the frequent presence of these peculiar vessels in normal fascia often well removed from the proliferative nodules. These peculiar perivascular cells sometimes appeared to be the origin of the proliferative nodules.

Another interesting feature, and one which has given rise to much controversy, was the finding of inflammatory cells; their presence was observed in nearly every case. Almost always they consisted predominantly of lymphocytes, but there were also mononuclear cells and occasional neutrophils. Characteristically the cells were perivascular in location and well away from the proliferative nodules. The vessels in these areas sometimes showed the proliferative cuffing already described. When accessory cutaneous structures were included in the section, these inflammatory cells were often seen surrounding sweat glands. Usually the inflammatory component of the lesion was not a striking characteristic, but in some specimens it was fairly pronounced. Only rarely did we observe a few scattered inflammatory cells within the foci of growth.

Skin was included in only a few specimens. Sweat glands were identified occasionally. The proliferating nodules were sometimes in close proximity, and in one case the sweat glands were surrounded by dense fibrous tissue.

In only one case was there evidence of invasiveness, demonstrated by inclusion of muscle cells within the proliferating tissue. It was difficult to interpret this feature, since four surgical operations had been done previously for this lesion. One of the sections in this same case showed a traumatic neuroma.

Clinical Data

The sex distribution in these sixty-nine cases of plantar fibromatosis was forty-three males and twenty-six females.

The age at onset was less than thirty years in twenty-four cases (35 per cent.). In two cases the lesion was present at birth. After the age of thirty the incidence of onset of the lesion showed a progressive increase in the fourth, fifth, and sixth decades of life (11, 16, and 24 per cent., respectively).

Involvement of the right foot only was present in eighteen cases, whereas the left foot only was involved in twenty-four; in twenty-seven cases the lesion was bilateral.

Twenty-three patients stated that they had noted pain. This varied in severity from infrequent mild pain after long standing or walking to pain which was severe enough to incapacitate the patient. Fourteen patients had not experienced pain. The records concerning thirty-two patients did not state whether or not pain was present; in these patients it may be inferred that pain was not present or was not prominent.

Recurrence after Surgical Excision

In twenty-eight cases a single excision only had been performed; the lesion recurred in fifteen of these cases. In five of the twenty-eight cases there was no recurrence. In the remaining eight cases it is not known whether or not recurrence took place.

Two excisions were performed in seven cases; known recurrence took place in four of these. In one case no recurrence was present seven years after the later operation and in another no recurrence was present four years after surgical treatment. It was not stated whether or not recurrence took place in the remaining instance.

The lesions were excised three or more times in three cases. In one of these cases the lesion was excised from the right foot three times within three months. When it recurred the foot was amputated. A lesion developed later in the opposite foot. In one case the lesion was excised four times within three and one-half years, yet it again recurred. Five excisions were done over a ten-year period in the third case; the lesion recurred and has persisted. These clinical data include three cases in which excision was done elsewhere, in addition to the thirty-five cases in which excision was done at the Clinic.

In seven cases, treatment with radium or roentgen rays, or both, was used in addition to excision; no apparent beneficial effect was noted.

The interval between surgical excision and recurrence was less than three months in eight cases, in two of which the lesions recurred almost immediately. In eight cases the lesions recurred six months to one year after operation. In four cases the lesions recurred between one and two years after excision. The interval was not recorded in two cases.

Course

The course of the disease is long and may extend over the patient's lifetime. We were especially interested in the course of the lesion when the onset was early in life. This series included eight patients who were less than twenty years of age when the lesion appeared. In only one of these, a seventeen-year-old girl, was the lesion bilateral; none of them had associated palmar lesions. Three cases are of special interest to illustrate the natural course of the disease.

A man, thirty-three years old, was seen at the Clinic in 1915, at which time a tumor was removed from the sole of the right foot. The lesion had been present since childhood. At the last follow-up, in 1952, the patient was seventy-one years of age. The lesion had recurred on the foot within one year after operation, but had given no further trouble. At present both hands are involved.

A man, twenty-three years old, had noticed a tumor in the sole of the left foot for about fifteen years. Within the year preceding admission he had noted similar involvement of the right foot and Dupuytren's contracture of both hands.

A thirty-year-old man had noted a tumor in the sole of the right foot since childhood. Involvement of the left hand had become evident seven years prior to admission, and one and a half years before admission lesions had been noted in the right hand. One year before the patient was admitted, a tumor had appeared in the sole of the left foot.

Association with Fibromatosis Elsewhere

In twenty-four cases the lesion involved the plantar fascia only and in each of these the diagnosis was proved histologically.

In forty-five cases both palmar and plantar fascia was involved. The order of occurrence was recorded in twenty-six of these cases. In fourteen of them the lesion appeared first in the hands. Ten years or more had elapsed before the lesion appeared in the feet in four cases, whereas five to ten years had passed in eight cases; in the remaining two cases the interval was four years.

In ten of the twenty-six cases in which the order of occurrence was noted, the lesions appeared first in the feet. In three cases the intervals before the lesions appeared in the hand were twenty, thirty, and forty years, respectively. In two cases the time interval was ten to twenty years. In three cases the interval was two to five years. In the remaining

two cases the lesions appeared in the hands less than one year after they had been noted in the feet, the intervals being two and two and one-half months, respectively.

In the remaining two of the twenty-six cases in which the order of occurrence was noted the lesions appeared simultaneously in both palmar and plantar fascia.

Penis plasticus (Peyronie's disease) was associated in three cases. In two of these there was involvement of the plantar fascia only, and in one there was involvement of both feet and both hands.

Knuckle pads were present in three cases, in all of which both the palmar and plantar fascia was involved.

Keloids were associated in four cases. In two of these both palmar and plantar fascia was involved, whereas only plantar fascial lesions were present in two.

Firm subcutaneous nodules were noted in ligamentous tissue elsewhere in two cases, in each of which involvement of both palms and both soles was present. Bilateral involvement of the tensor fasciae femoris was noted in one of these. In the second case firm subcutaneous nodules were noted over the flexor tendons of both wrists and in the tendons of both shoulders; knuckle pads were also present.

Desmoid tumors were not found in any of our cases.

Epilepsy was present in three of the sixty-nine cases. Craniotomy was performed in one of these and an intracerebral dermoid cyst containing hair and sebaceous material was discovered. The patient died after operation.

Comment

It is apparent that plantar fibromatosis has been mistaken in times past for a malignant neoplasm. In our series, a histological diagnosis of fibrosarcoma was made originally in eight cases; in two of these the diagnosis appeared to be corroborated clinically on the basis of rapid recurrence after operation. These erroneous diagnoses were made twenty years ago or more, before sufficient experience had accumulated to permit clinical and pathological definition of the lesion.

Amputation for this lesion was performed in only one of our cases.

A woman, fifty-eight years old, noted a tender mass in the right sole. This tumor was excised but recurred within two weeks. Excision was again performed and within one month the lesion had again recurred. At this time the foot was amputated. As indicated previously, six months later a similar nodule appeared in the left sole. Two years later this lesion was excised; follow-up examination fourteen years later showed no recurrence.

The actively proliferating nodules of fibroblasts, sometimes showing cellular variability, mitotic figures and, rarely, invasive properties, easily may be mistaken histologically for a malignant neoplasm. Nevertheless, we consider that the microscopic features are highly distinctive.

If the lesion is associated with palmar lesions or Peyronie's disease, or if both feet are involved, the diagnosis is almost certainly plantar fibromatosis. In the eight cases in our series in which an erroneous diagnosis of malignant neoplasm was made, the lesion affected one foot only in three cases, both feet in two cases, one foot and both hands in one case, and one foot and one hand in one case; involvement of one foot in association with Peyronie's disease was present in the eighth case. Clinically these lesions exhibit other features which may render it difficult to differentiate them from malignant neoplasms. The lesion may recur rapidly after excision. Excision of a single mass may be followed by recurrence in the form of multiple nodules. The lesion in plantar fibromatosis, like a malignant neoplasm, is sometimes adherent to the skin and in some instances to the deep structures of the sole of the foot.

Follow-up information in our series emphasized the fact that plantar fibromatosis is a benign process. No instance of metastasis was found, although many local recurrences of the lesions were noted in some cases. The duration of follow-up studies in this series

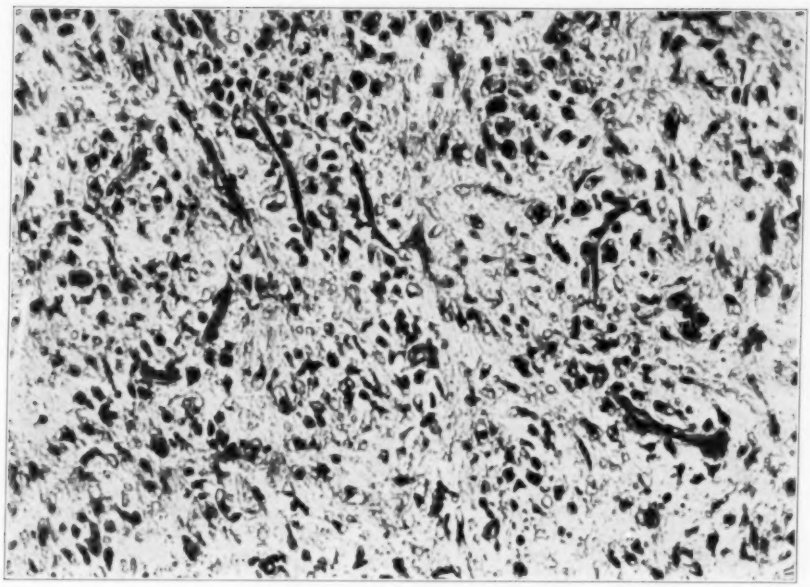

FIG. 4

Case 1. The specimen (× 250; hematoxylin and eosin stain) is taken from a liposarcoma of the sole. The neoplastic cells are large and vacuolated and contain sudanophilic material.

covered a period up to thirty-nine years; the period was more than five years in nineteen cases. In some cases, as already mentioned, the lesions appeared first in the foot, to be followed after a variable period by involvement of the fascia of one or both palms, the latter lesion admittedly being a benign one. We have been unable to find any evidence in the literature or in our series to indicate that plantar fibromatosis pursues the course of a malignant neoplasm.

MALIGNANT NEOPLASMS OF THE SOFT TISSUES OF THE SOLE

We have been able to discover only five reports of malignant soft-tissue tumors of the sole. In a report of fifteen cases of synovioma, Coley and Pierson, in 1937, described one case in which the lesion began in the sole.

Briggs, in 1942, reported a series of nine cases of synovioma, in one of which the lesion was located in the sole.

In 1940, Collins and Anspach reported on a nineteen-year-old man who, at the age of fourteen years, had noted soreness in the right sole; about one year later a swelling appeared. When he was sixteen years of age, a biopsy specimen was obtained and a diagnosis of fibrosarcoma was made; amputation was advised but was refused. Roentgen-ray treatment was given. Two years later biopsy of lymph nodes from the right groin revealed metastatic spindle-cell sarcoma. One year later widespread pulmonary metastasis appeared and the patient died.

Zarzecki reported a series of thirty-eight cases of fibrosarcoma of the extremities. In one case, in which death occurred, the tumor was located on the plantar surface of the foot.

Bennett reported a study of thirty-two synoviomata in 1947; he found one case in which the neoplasm was located on the sole.

In our material, the soft-tissue tumors presenting in the sole could be divided into two sharply defined categories, namely, the benign lesions, consisting entirely of plantar fibromatosis, and the malignant neoplasms. There were no instances of benign tumors

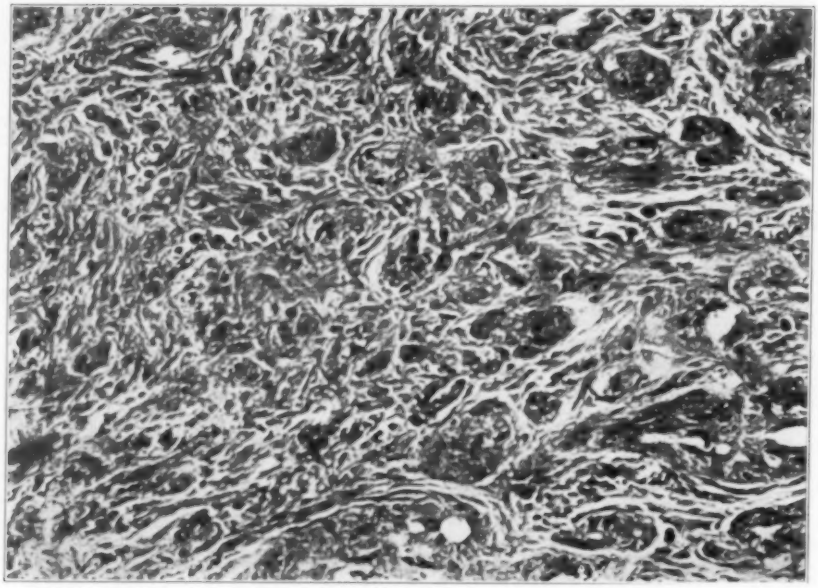

FIG. 5

Case 2. Specimen (× 250; hematoxylin and eosin stain) from a synovioma of the sole. The characteristic appearance of the glandlike spaces and the malignant fibrous-tissue component is shown.

arising from nerves, blood vessels, muscles, or other soft-tissue components. As indicated previously, we found nine cases of malignant neoplasms of the soft tissues of the sole.

REPORT OF CASES

CASE 1. A woman, sixty-five years old, had noted a tumor on the right sole for three years. The mass was not painful but interfered with wearing a shoe. The lesion had been excised one and one-half years before admission and again nine months before admission, but each time it had recurred soon after operation. Examination revealed a soft tumor in the sole; it measured four centimeters in diameter and was attached to the skin. The lesion was excised and was diagnosed histologically as liposarcoma (Fig. 4). Amputation was refused by the patient. The tumor had not recurred ten months after operation.

CASE 2. A man, thirty-four years old, first noticed a lump in the left instep nine years before admission; five years before admission the tumor was excised, but it recurred and grew slowly until eight months before admission, when it was again excised. The site of surgical excision had failed to heal, and a persistent draining sinus was present. Examination disclosed a soft tumor which measured six centimeters in diameter and occupied the entire mid-portion of the left sole. The foot was amputated at the ankle. The patient died of pulmonary metastasis one and one-half years later. The surgical specimen showed extensive involvement of the soft-tissue structures of the sole by the tumor. Histological examination revealed a synovioma (Fig. 5).

CASE 3. A man, forty-six years old, came to the Clinic because of a tumor in the arch of the right foot of fifteen months' duration. Six months before admission a two-centimeter tumor had been excised from the right foot; it recurred, grew rapidly, and was again excised three months later. Examination showed a soft, tender subcutaneous tumor measuring three centimeters in diameter and occupying the mid-portion of the right sole. A mid-thigh amputation was performed. The patient died one and one-half years later with roentgenographic evidence of extensive pulmonary metastasis. The surgical specimen showed extensive involvement of all the soft tissues of the sole by the tumor. Histological examination showed the tumor to be synovioma.

CASE 4. A man, forty-four years old, came to the Clinic because of swelling in the left sole of four years' duration. Six months before admission the foot had become swollen and painful and appeared fluctuant. The tumor was "lanced" without relief and a draining sinus had persisted. Examination disclosed a large, soft,

tender mass occupying the left sole. A below-the-knee amputation was performed. The patient died one and one-half years later with roentgenographic evidence of extensive pulmonary metastasis. The surgical specimen showed extensive involvement of all the soft-tissue structures of the sole by the tumor. Histological examination revealed a synovioma.

CASE 5. A sixteen-year-old boy came to the Clinic because of a tumor in the right sole of nine years' duration. Two years after onset the mass had reached a diameter of one centimeter; it was excised but was not examined histologically. Nine months before admission a painless mass had appeared in the right groin. Two weeks before admission this mass, which was the size of a walnut, had been excised and a diagnosis of sarcoma had been made. Examination disclosed an unhealed inguinal surgical incision. In the right sole was a firm, freely movable nodule measuring 1.5 centimeters in diameter; this mass was excised and was reported to be a sarcoma. Roentgen-ray therapy was given after operation. Six years later an abdominal mass and ascites developed and the patient died. Necropsy was not performed, but the patient was considered to have metastatic sarcoma. Histological examination of the tumor excised from the foot revealed a synovioma.

CASE 6. A man, twenty-seven years old, came to the Clinic because of a swelling of the right sole of six months' duration. The mass had become fluctuant and four days before admission had been incised, with drainage of what appeared to be purulent material. Examination revealed a large, soft, tender mass which occupied the entire mid-portion of the right sole. Roentgenographic examination showed destruction of the tarsal bones. Biopsy of the lesion revealed sarcoma and a below-the-knee amputation was performed; fifteen months later the patient died of pulmonary metastasis. The surgical specimen showed extensive involvement of the soft tissues of the sole and destruction of the tarsal bones by the tumor. Histological examination disclosed that the tumor was a synovioma.

CASE 7. A man, forty-eight years old, came to the Clinic because of a tumor of the left sole of unstated duration. Two years before admission a small tumor had been excised from the arch of the left foot and had been diagnosed as a fibroma; the tumor recurred almost immediately. Examination showed a large mass occupying the arch and most of the sole of the left foot. A below-the-knee amputation was performed. The patient died one and one-half years later of extensive pulmonary metastasis. The surgical specimen showed extensive involvement of the soft tissues of the sole by the tumor. Histologically the tumor was found to be a synovioma.

CASE 8. A man, forty-six years old, had noted three small nodules on the dorsum and a larger tumor in the sole of the right foot for six months. These had grown slowly. One month before admission one of the nodules had been excised and a histological diagnosis of sarcoma had been made. Examination revealed three firm nodules on the dorsum of the right foot and a larger tumor which bulged in the arch of the foot. Amputation through the lower portion of the thigh was performed. Thoracic roentgenograms revealed widespread pulmonary metastasis two and one-half years later. The patient was lost to follow-up. Histological examination showed that the tumor was a synovioma.

CASE 9. A thirty-year-old woman came to the Clinic because of a tumor in the left sole of two years' duration. The mass had grown slowly and was painful on walking and at night. Nine months before admission the tumor, which had reached a diameter of five centimeters, had been excised. Four months later a mass had reappeared and soon after similar, smaller nodules had appeared in the sole. The lesions were extremely painful. Examination disclosed a tender mass measuring five by seven centimeters and occupying the mid-portion of the left sole. The leg was amputated; one and one-half years later the patient died with the clinical diagnosis of metastatic sarcoma. Histological examination showed the tumor to be synovioma.

SUMMARY AND CONCLUSIONS

Sixty-nine cases of plantar fibromatosis and nine cases of malignant neoplasms involving the soft tissues of the sole form the basis of this study. Of the nine malignant neoplasms in this series, eight were synoviomata and one was a liposarcoma. The behavior of these tumors in the foot does not differ from that of such tumors elsewhere in the body.

In twenty-four of the sixty-nine cases of plantar fibromatosis in this series, the lesions involved plantar fascia only; in the remaining forty-five cases, both palmar and plantar fascia was involved. Peyronie's disease was found in three cases. Knuckle pads were present in three cases and keloids were associated in four. Firm subcutaneous nodules in ligamentous tissue elsewhere were noted in two cases.

The average age of onset of plantar fibromatosis was in the fourth decade of life. One third of the patients were younger than thirty years at the time of onset; the lesion was

congenital in two patients. There were forty-three males and twenty-six females in this series of sixty-nine cases of plantar fibromatosis. Following surgical excision in thirty-eight cases of plantar fibromatosis in this series, the lesion is known to have recurred in twenty-five cases, in most instances within one year after operation.

The course of plantar fibromatosis is apt to be long and only slowly progressive. In the great majority of cases the lesion is relatively asymptomatic. Pain is usually infrequent and mild.

Fibromatosis may be mistaken histologically for a malignant neoplasm on the basis of actively proliferating fibroblasts, cellular variability, mitotic figures, and, on occasions — especially after previous surgical treatment — apparently invasive properties. The histological features are diagnostic to the pathologist familiar with this lesion.

Plantar fibromatosis is a benign lesion. There is no evidence that the lesion ever becomes malignant.

REFERENCES

1. Bennett, G. A.: Malignant Neoplasms Originating in Synovial Tissues (Synoviomata). A Study of Thirty-two Specimens Registered at the Army Institute of Pathology During the War-Time Period, 1941–1945. J. Bone and Joint Surg., **29:** 259–291, Apr. 1947.
2. Briggs, C. D.: Malignant Tumors of Synovial Origin. Ann. Surg., **115:** 413–426, 1942.
3. Bunnell, Sterling: Surgery of the Hand. Ed. 2, pp. 210–221. Philadelphia, J. B. Lippincott Co., 1948.
4. Clay, R. C.: Dupuytren's Contracture. Fibroma of the Palmar Fascia. Ann. Surg., **120:** 224–231, 1944.
5. Coley, B. L., and Pierson, J. C.: Synovioma. Report of Fifteen Cases with Review of Literature. Surgery, **1:** 113–124, 1937.
6. Collins, N. C., and Anspach, W. E.: Fibrosarcoma of Plantar Tissues. Am. J. Cancer, **40:** 465–470, 1940.
7. Dupuytren, Guillaume: De la rétraction des doigts par suite d'une affection de l'aponévrose palmaire. Description de la maladie. Opération chirurgicale qui convient dans de cas. Med. Class., **4:** 127–141, 1939.
8. Hammond, George, and Dotter, W. E.: Quadrilateral Dupuytren's Contracture. A Case Report. Guthrie Clin. Bull., **18:** 34–38, 1948.
9. Iklé, Curt: Zur Histologie und Pathogenese der Dupuytrenschen Kontraktur. Deutsche Zeitschr. f. Chir., **212:** 106–118, 1928.
10. Janssen, Peter: Zur Lehre von der Dupuytrenschen Fingercontractur, mit besonderer Berücksichtigung der operativen Beseitigung und der pathologischen Anatomie des Leidens. Arch. f. Klin. Chir., **67:** 761–789, 1902.
11. Kanavel, A. B.; Koch, S. L.; and Mason, M. L.: Dupuytren's Contraction. With a Description of the Palmar Fascia, a Review of the Literature, and a Report of Twenty-nine Surgically Treated Cases. Surg., Gynec., and Obstet., **48:** 145–190, 1929.
12. Kapiloff, Bernard, and Prior, J. T.: Fibromatosis in Children. Plast. and Reconstruct. Surg., **10:** 276–282, 1952.
13. Keasbey, L. E.: Juvenile Aponeurotic Fibroma (Calcifying Fibroma). A Distinctive Tumor Arising in the Palms and Soles of Young Children. Cancer, **6:** 338–346, 1953.
14. Langhans: *In* Kocher, Theodor: Behandlung der Retraktion der Palmaraponeurose. Centralbl. f. Chir., **14:** 497–502, 1887.
15. Ledderhose: Zur Pathologie der Aponeurose des Fusses und der Hand. Arch. f. Klin. Chir., **55:** 694–712, 1897.
16. Lund, Mogens: Dupuytren's Contracture and Epilepsy. The clinical connection between Dupuytren's contracture, fibroma plantae, periarthrosis humeri, helodermia, induratio penis plastica and epilepsy, with an attempt at a pathogenetic valuation. Acta Psychiat. et Neurol., **16:** 465–492, 1941.
17. Meyerding, H. W.; Black, J. R.; and Broders, A. C.: The Etiology and Pathology of Dupuytren's Contracture. Surg., Gynec., and Obstet., **72:** 582–590, 1941.
18. Meyerding, H. W., and Shellito, J. G.: Dupuytren's Contracture of the Foot. J. Internat. Coll. Surg., **11:** 595–603, 1948.
19. Pickren, J. W.; Smith, A. G.; Stevenson, T. W.; and Stout, A. P.: Fibromatosis of the Plantar Fascia. Cancer, **4:** 846–856, 1951.
20. Skoog, Tord: Dupuytren's Contraction. With Special Reference to Aetiology and Improved Surgical Treatment. Its Occurrence in Epileptics. Note on Knuckle Pads. Acta Chir. Scandinavica, **96** (Supplementum 139): 1–190, 1948.
21. Zarzecki, C. A.: Fibrosarcoma of the Extremities. A Review of Thirty-eight Cases. North Carolina Med. J., **10:** 605–607, 1949.

THE SURGICAL MANAGEMENT OF RESIDUAL DEFORMITIES OF THE SHOULDER FOLLOWING BIRTH INJURIES OF THE BRACHIAL PLEXUS *

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The purpose of this presentation is to report on the management of fifty-four patients with birth injuries of the brachial plexus and especially to evaluate various operative procedures employed to correct residual deformities of the shoulder in twenty-four of these patients.

Paralysis of the arm resulting from injuries to the brachial plexus sustained at birth has been recognized since Smellie mentioned the entity in a book on midwifery published in 1764. Duchenne, Erb, and Klumpke subsequently described the mechanism of injury and site of nerve trauma producing the types of paralysis which have since been associated with their names. During the later part of the nineteenth century and early part of the twentieth century numerous articles appeared by Fieux, Schoemaker, Fairbank, Taylor [28,29], Danyau, Boyer, and Sever, to name but a few, from which has evolved much of our present concept of the pathological anatomy and the basic principles of management of birth injuries of the brachial plexus.

As a result of improved obstetrical techniques, the incidence of birth palsies has decreased. With the decrease in incidence there has been a decrease in interest in the problem, as is apparent from the relatively few articles which have appeared in the recent literature.

CLASSIFICATION

Rather than to attempt to group our patients according to the classic descriptions of Erb and Duchenne or of Klumpke, we have classified them according to the components of the plexus injured (upper component, lower component, or the entire plexus), the severity of damage as manifested by the extent of paralysis, and the degree of function achieved, as well as the time required for this. Of our fifty-four patients, thirty-six had principal involvement of the fifth and sixth cervical roots or their derivatives, four had involvement of the eighth cervical and first thoracic roots, and fourteen had some involvement of all components of the plexus.

In general, injuries of the upper components of the plexus were less severe than were injuries of the entire plexus or of the lower components. This may be explained by the larger size of the proximal portions of the cords and trunks and the more secure protection afforded by the enveloping fascial sheaths of the upper roots of the plexus [26].

Twenty-eight of the patients in this series were classified as having minimal damage to the components of the plexus. In most of these the upper roots were involved. Muscle power returned within three to six months without significant residual impairment of function in the arm. The authors postulate that the pathological anatomy present in these cases consisted of perineural adhesions and constricting cicatrices resulting from oedema of the plexus and epineural hemorrhage. This may be sufficient to impair axon function, as evidenced by demyelinization of the nerves above and below the site of constriction as described by Prout [6].

Increased traction on the plexus produces actual disruption of nerve fibers at multiple points along the course of the nerve.[4] Some fibers remain intact; others regenerate across

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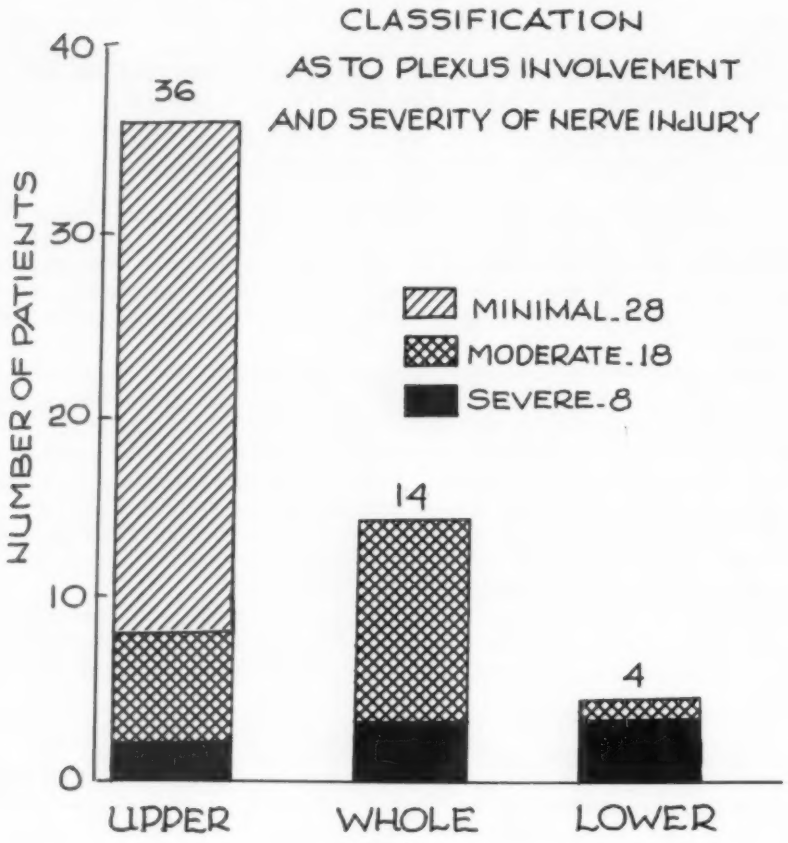

CHART I

the sites of separation, while still others become enmeshed in multiple neuromata. More severe stresses may completely disrupt the entire nerve. Such disruptions usually occur at the intervertebral foramen, but they may represent avulsions of roots from the spinal cord.[26] The lack of coordination and dyskinesia observed in those patients with moderate or severe plexus damage has been attributed to interruption of spinal-cord centers by Milgram. Gross pathological lesions of the spinal cord have been described by a number of authors [2,5,6].

There were eighteen patients in the group with nerve damage classified as moderate. These exhibited incomplete or poor recovery of function at the end of six to eighteen months.

Eight patients showed little or no improvement in motor function at the end of eighteen months and were classified as having severe damage. Three of these had Horner's syndrome (evidence of first thoracic-root damage) and four had root avulsion, as evidenced by paralysis of the rhomboids, levator scapulae, and serratus anterior (impairment of dorsal scapular and anterior thoracic nerves) [26]. Four had sensory-nerve as well as motor-nerve damage (Chart I).

TREATMENT

Non-operative management consisted in protection of the paralyzed muscles by pinning the arm above the head in newborn infants, followed by use of a modified Fairbank

TABLE I

RESPONSE TO NON-OPERATIVE REGIMEN IN FIFTY-FOUR PATIENTS

	Excellent		Satisfactory		Poor		Total	
	No.	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*	*No.*	*Per cent.*
Minimal damage	7	12.9	21	38.8			28	51.8
Moderate damage			2	3.7	16	29.6	18	33.3
Severe damage					8	14.8	8	14.8
Total	7	12.9	23	42.6	24	44.5	54	99.9

splint for three to five months. The splint was used at night for an additional three to twelve months. This was accompanied and followed by passive and assisted active motion carried out under the parents' supervision. As soon as cooperation could be obtained from the child, active motion and the use of a shoulder-exercise wheel (improvised from bicycle wheels in various sizes) was insisted upon to maintain and increase the range of abduction and rotation in the shoulder. This regimen was not carried out in its entirety in patients first seen after infancy. Older children were started on the corrective exercises already described; an abduction splint was used in a few in an attempt to stretch contractures. The response to splinting in older children was discouraging.

Although twenty-eight patients with minimal nerve damage and two with moderate damage (55.5 per cent.) showed adequate response to conservative therapy in from three to six months, only seven (12.9 per cent.) had completely normal recovery of all shoulder, arm, and hand functions. Twenty-two showed some limitation of the range of external rotation and abduction and one had slight limitation of internal rotation and abduction. In spite of the limitation of the range of abduction, these shoulders were held in a position of 10 to 15 degrees of abduction and were not adducted against the chest wall as the classic description implies. Sixteen patients (29.6 per cent.) with moderate nerve damage responded rather poorly to non-operative management for six to eighteen months and the eight patients (14.7 per cent.) with severe nerve damage showed poor return of function in spite of a conservative regimen for as long as twenty-eight months (Table I).

RESIDUAL DEFORMITIES OF THE SHOULDER

Analysis of the 87.1 per cent. of patients with varying degrees of residual impairment showed that the most common deformity was an internal-rotation contracture and limited abduction of the shoulder.

Although these patients presented a variety of other abnormalities of function and interesting problems of reconstruction, we have elected to evaluate the correction of the most common shoulder deformities, since all stem from the imbalance between the unimpaired internal rotators and the weak or paralyzed external rotators. If the shoulder remains in a position of marked internal rotation, secondary flattening of the humeral head and deformity of the glenoid cavity develop as the child grows. This occurred in six patients; in one of these it occurred bilaterally. Persistent tight internal rotation forces the humeral head posteriorly into the glenoid cavity and may result in posterior dislocation of the shoulder. This was observed in five patients.

Fairbank attributed posterior dislocation of the humerus to immobilization of the shoulder in an abduction splint which allows the shoulder to flex forward. We feel that the persistent position of tight internal rotation with attempts at flexion of the shoulder to bring the hand forward to the face probably produces the posterior displacement of the humeral head. Posterior dislocation occurred in two patients who had not been treated in an abduction splint.

"Beaking" and forward displacement of the acromion and downward prolongation of the coracoid are other bone deformities of the shoulder secondary to the internal-rotation contracture [23].

INDICATIONS FOR SURGERY

Internal-rotation contracture and weak abduction in the shoulder produce difficulty in bringing the hand to the mouth or to other portions of the head. Because of the combination of these two factors, we were unable to determine the exact degree of limitation of external rotation which could be used as an indication for surgical intervention. An internal-rotation contracture of more than 20 degrees, however, necessitates flexion of the head forward and toward the involved side, as well as awkward abduction and flexion of the shoulder to allow the hand to reach the mouth. If the internal-rotation contracture is more than 45 degrees and abduction of the shoulder is moderately limited, it may be impossible to bring the hand to the mouth. This is especially true if there is associated impairment of motion in the elbow, forearm, or wrist.

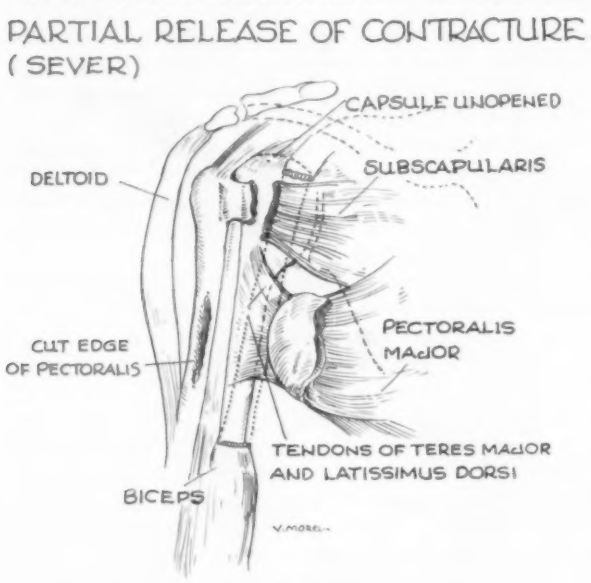

FIG. 1

All reconstructive procedures about the shoulder have as their objective an increase in the range of external rotation and abduction. If the glenohumeral joint is free of bone deformities, this objective may be obtained by simple tenotomies to release the contracted internal rotators; these procedures may be performed alone or they may be combined with tendon transplantation to increase the power of the external rotators. If dislocation or incongruity of the glenohumeral

FIG. 2-A FIG. 2-B

Fig. 1: Diagrammatic representation of the Sever release of the pectoralis major and subscapularis tendons in order partly to correct internal-rotation contracture. Note that the capsule is not disturbed and the teres major and latissimus dorsi tendons remain intact.

Figs. 2-A and 2-B: Photographs of an eleven-year-old boy seven years after a Sever operation. The increase of external rotation to 120 degrees immediately after operation gradually diminished to 55 degrees between the second and seventh year after operation.

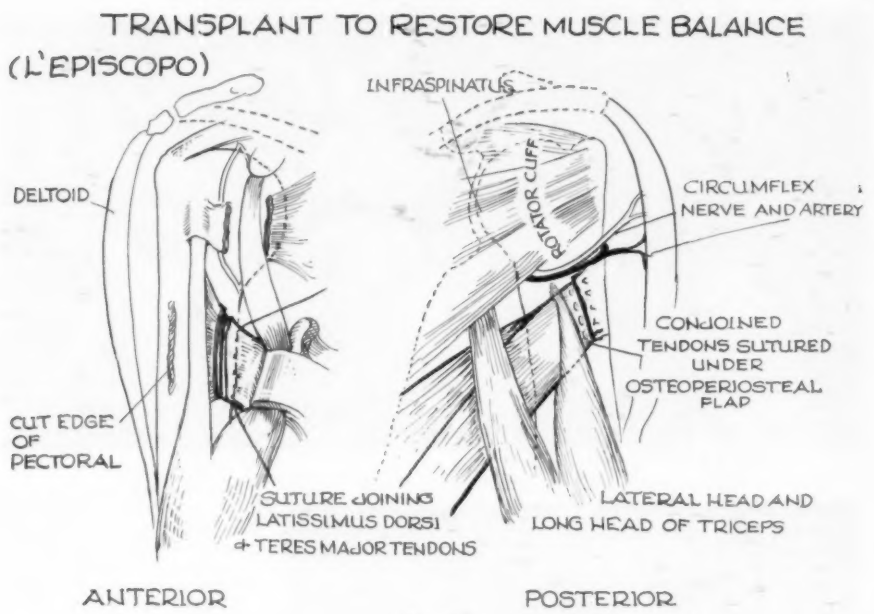

FIG. 3

Diagrammatic representation of the L'Episcopo tendon transplantation to restore muscle balance in the shoulder. The capsule is opened and the head of the humerus is inspected before the teres major and latissimus dorsi are transplanted posteriorly and laterally to act as external rotators.

joint is present, release of contractures or tendon transplantation cannot be expected to improve the function or the position of the extremity. Open reduction of the shoulder or osteotomy of the humeral shaft must then be resorted to. There were twenty-four patients in this series with sufficient dysfunction of the extremity, because of shoulder deformity, to warrant surgical intervention. Thirteen had surgical procedures of tendons and in eleven bone or joint procedures were required.

OPERATIVE PROCEDURES

Three patients had simple release of the internal-rotation contracture by sectioning of the pectoralis major and subscapularis muscles as advocated by Sever [22] (Fig. 1). All three showed improved external rotation of the shoulder without an increase in the range of abduction. One child maintained the increased range of external rotation for four years, at which time he was lost from further follow-up. The other two showed a gradual loss in the range of external rotation obtained at surgery; this was first noted at eight months and twenty-six months after operation, respectively. In one the improvement in the range of external rotation decreased 45 degrees (from 120 to 75 degrees) in five years; in the other, 65 degrees (from 120 to 55 degrees) in seven years (Figs. 2-A and 2-B).

Ten patients had release of the internal-rotation contracture by sectioning of the pectoralis major and subscapularis, together with transplantation of the teres major and latissimus dorsi attachment posteriorly and laterally under the lateral head of the triceps (Fig. 3). L'Episcopo [17,18] first described this technique in 1934 and modified the procedure in 1939. Kast published a similar technique in 1939 and stated it to be a modification of a transplantation described by Ansart. The results in this series were considered to be excellent in six cases and good in three; one was a failure. Those patients with excellent results had an improvement in the range of external rotation to at least 120 degrees and abduction to 120 degrees (Figs. 4-A, 4-B, and 4-C). The three with good results exhibited

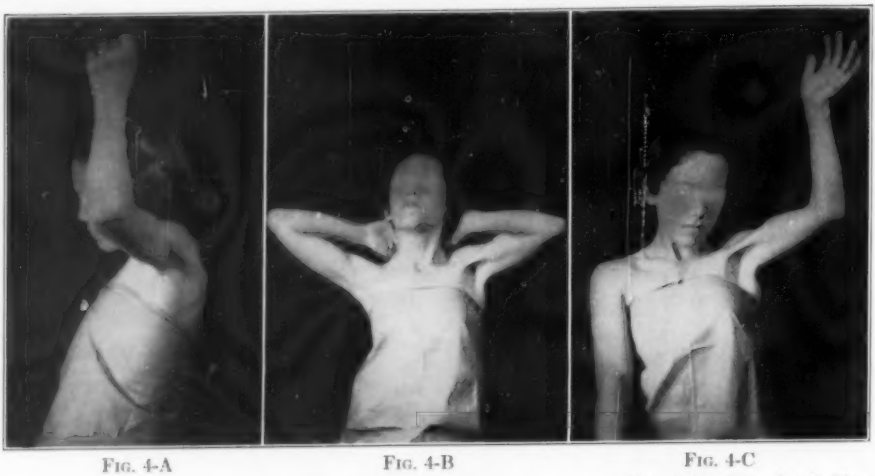

FIG. 4-A FIG. 4-B FIG. 4-C

Figs. 4-A, 4-B, and 4-C: Photographs of a thirteen-year-old girl five years after the L'Episcopo operation on the left shoulder. The preoperative range of abduction had been from 15 to 55 degrees, and of external rotation from 0 to 40 degrees. Postoperatively the range of abduction improved from 15 to 120 degrees and external rotation from 0 to 120 degrees.

FIG. 5-A FIG. 5-B

Figs. 5-A and 5-B: Photographs of a sixteen-year-old girl four years after derotation osteotomy above the insertion of the deltoid muscle. Before surgery a limited range of external rotation — from 0 to 120 degrees — had prevented her from bringing her hand to her mouth. After operation an increase of 20 degrees in the range of abduction (to 90 degrees) was also obtained.

FIG. 6

Fig. 6: Photograph of a seven-year-old boy two years after osteotomies of both humeri to correct severe internal-rotation contractures. This child could oppose only the back of his hands below his waist and had developed the prehensile function of his toes to the point where he ate with his feet. In addition to the derotation osteotomies, a number of other procedures were required to correct deformities in the elbow, wrist, and hand and to salvage residual function. Abduction in the right shoulder increased from 60 to 95 degrees and in the left shoulder from 40 to 110 degrees after operation.

an improved range of external rotation to 100 degrees and abduction to 100 degrees. The one failure resulted from incongruity of the joint not recognized preoperatively or at the time of surgery. In contrast to the patients who after the Sever procedure had gradual loss of improvement in the range of external rotation, motion in the patients in this last group appeared to improve at subsequent examinations. The period of follow-up in this group varied from one to five years.

There were six patients who exhibited flattening of the humeral head or incongruity of

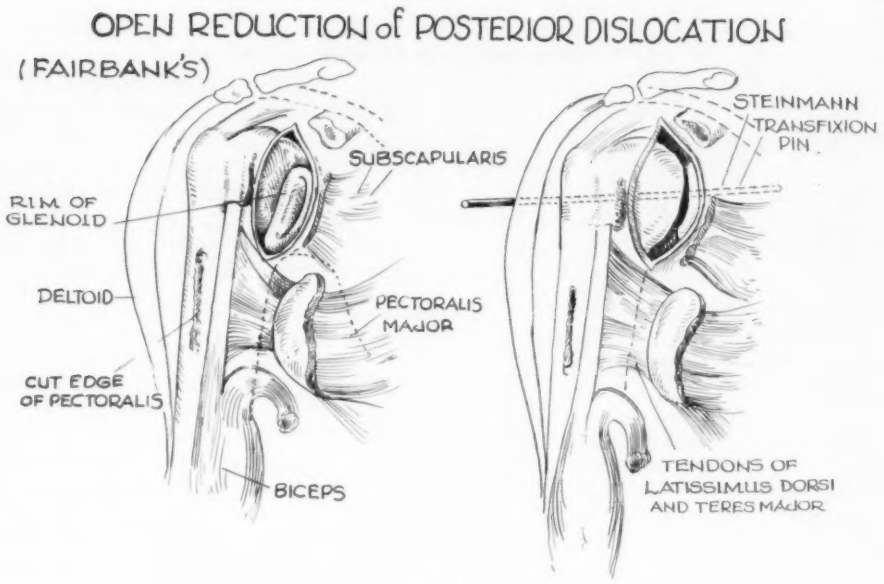

FIG. 7

Schematic drawing of Fairbank's open reduction of a posterior dislocation of the humeral head after sectioning of the pectoralis major and subscapularis tendons. Removal of a portion of the coracoid process when it projects downward is frequently necessary to secure reduction. The transfixing pin is cut immediately below the skin and removed after four weeks.

the glenohumeral joint of sufficient degree to prevent rotation of the humerus. An osteotomy of the humeral diaphysis above the insertion of the deltoid was performed, which allowed the head to remain in its position of internal rotation, while the arm was externally rotated into a position of function. The amount of external rotation was determined at operation by actual testing. A position which would allow the hand to be brought to the mouth by flexion of the elbow with the arm at the side was selected

FIG. 8-A FIG. 8-B FIG. 8-C

Photographs of a twelve-year-old child three years after open reduction of a posterior dislocation of the shoulder. The preoperative range of abduction had been from 15 to 75 degrees; after operation this range was to 140 degrees. External rotation, which before operation had been limited to 50 degrees, is now possible to 130 degrees.

TABLE II

RESULTS OF RECONSTRUCTIVE SURGERY IN TWENTY-FOUR PATIENTS

Procedure	No. of Patients	Results		
		Excellent	Satisfactory	Failure
Sever	3	1		2
L'Episcopo	10	6	3	1
Fairbank	5	4		1
Osteotomy*	6		6	
Total	24	11	9	4†

* Osteotomy did not increase function of the shoulder to the same degree as other reconstruction procedures, because of the more severe pathological involvement in these cases.

† Arthrodesis was performed in one of the patients in whom there had been failure and is anticipated in another.

and was then maintained by internal fixation. This procedure did not restore excellent function to the shoulder, but did allow the hand to be brought to the mouth without conspicuous forward flexion of the shoulder or lateral bending of the head and neck. Two patients did exhibit increased range of abduction following osteotomy (Figs. 5-A, 5-B, and 6). L'Episcopo suggested that lateral rotation of the deltoid insertion below the osteotomy site afforded a mechanical advantage for deltoid action. This factor, together with the intensive postoperative exercises, probably accounts for the improvement in abduction observed.

Five patients had posterior dislocation of the humeral head with fixed internal-rotation deformity of the shoulder. Open reduction of the dislocation, with release of the pectoralis major and subscapularis as described by Fairbank, was performed, but was modified by transfixing the humeral head to the glenoid cavity in external rotation with a Steinmann pin for four weeks after operation (Fig. 7). Immobilization of the shoulder was continued for an additional three weeks after removal of the pin. Restoration of function to the shoulder was excellent in four patients (Figs. 8-A, 8-B, and 8-C); one patient, however, continued to have posterior subluxation, experienced pain, and had little improvement in function. Arthrodesis of the shoulder is anticipated in this case.

DISCUSSION

Twenty of the twenty-four patients who had various types of reconstructive procedures about the shoulder had excellent or satisfactory improvement in motion at the shoulder or in function of the extremity. Those patients with less severe plexus damage and more normal residual function in the elbow, forearm, and wrist showed the greatest improvement in function after surgical correction of the internal-rotation contracture of the shoulder. It must be pointed out that, even in those patients with more severe damage to the plexus and poor residual function of the arm, significant, and sometimes surprising, improvement in function followed correction of the shoulder deformity. Restoration of the position of function to the arm was paralleled by an increase in use and function of the arm.

Active external rotation was not only more complete immediately after operation in those patients who underwent the L'Episcopo procedure, but was maintained better than in those who had the Sever operation. We believe the gradual decrease in the range of external rotation observed in two thirds of this second group results from two factors: first, the failure completely to release the internal-rotation force contributed by the latissimus dorsi and subscapularis and, second, the failure to increase the power of external rotation. The increase in operative time and the technical difficulties of the L'Episcopo transplantation appear to be justified.

Other transplantations about the shoulder have been performed by Moore and Barr.

Moore's transplantation of a portion of the anterior half of the origin of the deltoid to the scapular spine reportedly improved lateral abduction of the arm. Barr has transplanted the subscapularis tendon posteriorly and laterally to function as an external rotator. We have had no personal experience with either procedure.

Direct repair of the plexus as advocated by Kennedy and by Taylor [6,28,29] does not appear to improve the function over that attained by non-operative treatment and was not employed in any of our patients.

The improvement in function of the entire arm noted when deformities of the shoulder had been corrected has been a most striking feature in those patients with posterior dislocation of the humeral head. Successful reduction of the shoulder restored the arm to a position of function and increased the efficiency and function in all components of the arm. Although no attempt was made to repair or to reinforce the capsule or other structures in the front of the shoulder, none of the shoulders have dislocated anteriorly. As noted previously, one subluxated posteriorly and was classed as a failure.

The improvement in function of the whole arm which paralleled improvement in position was again noted in those patients in whom derotation osteotomies of the humerus were performed above the insertion of the deltoid. The increased difficulties of osteotomizing the humerus at this site seem to be justified by the increase in function of the deltoid noted in several patients. The authors recognize the role which concentrated activity and exercise have played in the improvement noted, but they believe that the major factor in increased function has been restoration of the arm to a position of function.

REFERENCES

1. Ansart, Bastos: Quoted by Erlacher [10].
2. Boyer, G. F.: The Complete Histo-pathological Examination of the Nervous System of an Unusual Case of Obstetrical Paralysis Forty-one Years after Birth, and a Review of the Pathology. Proc. Roy. Soc. Med. (Neurol. Sect.), **5:** 31–58, 1911.
3. Bunnell, Sterling: Surgery of the Hand. Ed. 1, pp. 413–415. Philadelphia, J. B. Lippincott, 1944.
4. Barr, J. S.: Personal communication.
5. Burr, C. R.: Spinal Birth Palsies: A Study of Nine Cases of "Obstetric Paralysis". Boston Med. and Surg. J., **127:** 235–238, 1892.
6. Clark, L. P.; Taylor, A. S.; and Prout, T. P.: A Study on Brachial Birth Palsy. Am. J. Med. Sciences, **130:** 670–707, 1905.
7. Danyau: Quoted by Stransky [27].
8. Duchenne, G. B. A.: De l'Électrisation Localisée et de son Application à la Pathologie et à la Thérapeutique. Ed. 3, pp. 357–362. Paris, Baillière, 1872.
9. Erb, W. H.: Ueber eine eigenthümliche Localisation von Lähmungen im Plexus brachialis. Verhandl. d. Naturhist.-Med. Ver. Heidelberg, n. F. **2:** 130–137, 1874.
10. Erlacher, E. B.: Die Technik des Orthopädischen Eingriffes. Plastik nach Bastos Ansart. Wien, Julius Springer, 1928.
11. Fairbank, H. A. T.: Birth Palsy: Subluxation of Shoulder-Joint in Infants and Young Children. Lancet, **1:** 1217–1223, 1913.
12. Fieux: Paralysie obstétricale du nouveau-né. (Abstract.) J. Méd. de Bordeaux, **26:** 526, 1896.
13. Kast, Hans: Über einen Fall von Muskelplastik bei Ausfall der Humerusaussenrotation. Der Chirurg, **11:** 111–112, 1939.
14. Kennedy, Robert: Suture of the Brachial Plexus in Birth Paralysis of the Upper Extremity. British Med. J., **1:** 298–301, 1903.
15. Kennedy, Robert: Further Notes on the Treatment of Birth Paralysis of the Upper Extremity by Suture of the Fifth and Sixth Cervical Nerves. British Med. J., **2:** 1065–1068, 1904.
16. Klumpke, A.: Contribution à l'étude des paralysies radiculaires du plexus brachial. Paralysies radiculaires totales. Paralysies radiculaires inférieures. De la participation des filets sympathiques oculo-pupillaires dans ces paralysies. Rev. de Méd., **5:** 591–616, 739–790, 1885.
17. L'Episcopo, J. B.: Tendon Transplantation in Obstetrical Paralysis. Am. J. Surg., **25:** 122–125, 1934.
18. L'Episcopo, J. B.: Restoration of Muscle Balance in the Treatment of Obstetrical Paralysis. New York State J. Med., **39:** 357–363, 1939.
19. Milgram, J. E.: Discussion of L'Episcopo's presentation [18].
20. Moore, B. H.: Brachial Birth Palsy. Am. J. Surg., **43:** 338–345, 1939.

21. Schoemaker, J.: Ueber die Aetiologie der Entbindungslähmungen, speciell der Oberarmparalysen. Zeitschr. f. Geburtsh. u. Gynäk., **41**: 33–53, 1899.
22. Sever, J. W.: Obstetric Paralysis. Its Etiology, Pathology, Clinical Aspects and Treatment, with a Report of Four Hundred and Seventy Cases. Am. J. Dis. Child., **12**: 541–578, 1916.
23. Sever, J. W.: The Results of a New Operation for Obstetrical Paralysis. Am. J. Orthop. Surg., **16**: 248–257, Apr. 1918.
24. Sever, J. W.: Obstetrical Paralysis. Surg., Gynec., and Obstet., **44**: 547–549, 1927.
25. Smellie, William: Collection of Preternatural Cases and Observations in Midwifery, Compleating the Design of Illustrating His First Volume on That Subject. Vol. III, pp. 504–505. London, 1764.
26. Stevens: Quoted by Bunnell [3].
27. Stransky, Erwin: Ueber Entbindungslähmungen der oberen Extremität beim Kinde. Centralbl. f. d. Grenzgeb. d. Med. u. Chir., **5**: 497–502, 1902.
28. Taylor, A. S.: Results from the Surgical Treatment of Brachial Birth Palsy. J. Am. Med. Assn., **48**: 96–104, 1907.
29. Taylor, A. S.: Brachial Birth Palsy and Injuries of Similar Type in Adults. Surg., Gynec., and Obstet., **30**: 494–502, 1920.

DISCUSSION

Dr. Carl E. Badgley, Ann Arbor, Michigan: After the preliminary treatment of the upper-arm type of brachial plexus palsy in the younger age group, we have found that not infrequently the arm is fixed in a fibrous ankylosis in abduction and external rotation. These children do exceedingly well until they grow older—about eight to ten years of age, when the added weight of the arm tends to diminish the fibrous ankylosis and the arm drops to the side. The only criticism the parents have of the child's progress prior to this time is the prominence of the scapula. I wish to emphasize that I believe that the ankylosing operation is an excellent procedure for those cases in which the L'Episcopo operation or rotation of the humerus cannot be used. We have been delighted with the L'Episcopo operation ever since we first read of the work. The indications for this operation are extremely simple. It should be performed when there is brachial plexus palsy but the ability to raise the arm passively in external rotation is present, although the arm cannot be actively raised. If bone changes are not marked, we can obtain external rotation with a Sever operation. We are then quite confident of a successful result with the transplantation of the L'Episcopo type and it has proved in our hands to be a most successful procedure. We also feel that in the older patients the osteotomy of the humerus has proved to be successful. It is most encouraging to see a return to an orthopaedic problem on this program; this is one of our old problems in orthopaedics.

Dr. Tom Outland, Harrisburg, Pennsylvania: This is probably the first time in a long while that the subject of obstetrical palsy has been presented to this group. Since it is a fairly common condition, although less so than formerly because of better obstetrics, it was inevitable that it eventually would be brought up. It was equally inevitable that the subject would be presented by a man filled with youthful vigor and enthusiasm, for this is one of the less glamorous conditions in what has come to be called "pediatric orthopaedics", (a redundancy, by the way, which must make Professor André stir restlessly in his grave). Obstetrical palsy is seen in all degrees of severity. Of the cases which are mild and reversible, probably only a small percentage are ever seen by the orthopaedist. In this type of case, treatment, beyond putting the joints of the entire extremity through a full range of passive motion several times daily, is of little importance and probably has no influence on the complete recovery which ensues. In the type of case seen commonly in orthopaedic practice, in which the deficit has persisted for six months or longer, complete recovery is rarely to be anticipated regardless of treatment and the various surgical procedures are, at best, patch-up efforts. This applies to the Sever operation, to humeral osteotomy, and to the tendon transposition with which Dr. Wickstrom and his associates are principally concerned. There should be a definite place for the L'Episcopo procedure in lesions of the upper components, even though standard textbooks would lead us to believe that such upper-arm lesions are no longer seen. There is a good reason for this. An injury of sufficient magnitude to produce the permanent changes of Erb's palsy is not likely to spare the other roots completely. If there is involvement of the hand, the need for finger grasp and thumb opposition is of infinitely greater moment than the need for external rotation at the shoulder and, if the former cannot be supplied, the condition of the shoulder is not of great practical importance. In that case, both of these lacks may be partially supplied by arthrodesis of the shoulder, provided, of course, that this is done at the proper age. This further restricts the number of cases in which transplantation of the teres major and latissimus dorsi is indicated.

My point should be quite apparent—namely that, in selecting cases for the L'Episcopo procedure, we must not fail to assess the importance of loss of external rotation in relation to the over-all disability of the extremity. I do not mean to imply that Dr. Wickstrom has made this mistake, but somebody else might. This will leave a relatively small group in which the operation may be done with considerable profit to the patient.

(*Continued on page 48*)

FAILURE OF EXCESS MINERALS IN THE DIET TO ACCELERATE THE HEALING OF EXPERIMENTAL FRACTURES *†

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In the experiments reported in this paper we have attempted to determine whether or not the addition of extra minerals to an already adequate diet will influence the healing of fractures. While some work has been done on the influence of inadequate nutrition upon fracture healing, we know of no observations upon the effect of excess minerals in the diet except those reported to the American Surgical Association in 1953 [3], in which fluorine in the amount of 226 parts per 1,000,000 was added to the drinking water of rats with experimental fractures. In those experiments there was no perceptible difference between the healing of fractures in the experimental animals and in the normal controls.

However, perusal of the series of papers by Sherman and his associates [5, 6, 7] led us to wonder if the addition of an excess of calcium to an adequate diet might not exert a favorable influence upon fracture healing. In their studies on nutrition, Sherman and Campbell noted that the addition of an increased amount of milk to an adequate diet in rats caused more rapid and efficient growth, larger size, earlier maturity, longer duration of reproductive life, increase in the number of young reared, and better growth of young. Sherman later recommended that the diet contain at least twice the minimum requirement of calcium. Sherman and Campbell stated that there is "a wide zone . . . between adequate and optimum nutrition". Sherman and Booher noted that rats on a low calcium diet (0.16 per cent.) may grow and appear well nourished, but that their bodies contained less calcium than did the bodies of rats of the same age which had been reared on a diet rich in calcium (0.5 per cent.).

On the other hand, in a series of studies on bone atrophy [2] it was concluded that: "Chronic local bone atrophy may occur from disuse and is not due to or markedly influenced by the calcium intake or calcium metabolism", and Fischer and Key noted that the experimental addition of excess vitamin D and calcium to the diets of children on an adequate diet did not perceptibly lessen bone atrophy of disuse or accelerate the rate of union by bone.

In a paper presented before the Texas Orthopaedic Society in May 1952, Barnett stated that fractures in the inhabitants of Deaf Smith County, which is located in the high plains of West Texas, differed from and healed more rapidly than did those which he encountered in Dallas, which is located in East Texas and is very different geographically. In support of this, he cited an experience of six years in Deaf Smith County, where he treated twenty-eight trochanteric fractures in patients whose average age was eighty-two years and obtained healing in all cases in an average time of eight weeks. During this period he did not see a single intracapsular fracture of the hip. In the Parkland Hospital at Dallas, Texas, a total of 468 fractures of the hip were treated between 1940 and 1950; 131 (28 per cent.) of these were trochanteric and 337 (72 per cent.) were fractures through the neck of the femur (intracapsular). The average age of the patients with trochanteric fractures was sixty-three years; the mortality was 11 per cent.; and the average healing time was 6.3 months.

Barnett also noted that the bones of Deaf Smith County inhabitants contained more bone ash, more calcium, and more magnesium and tended to cast a more dense shadow on

* Read at the Annual Meeting of The American Orthopaedic Association, Bretton Woods, New Hampshire, June 8, 1954.

† This investigation was supported by a research grant (A-436) from the National Institutes of Health of the Department of Health, Education, and Welfare Public Health Service.

roentgenograms than did the bones of subjects in the Dallas area. He then analyzed the water and food of the people of Deaf Smith County and determined the average daily consumption of minerals. A mixture of the minerals was prepared on the basis of these data for experimental, clinical, and laboratory trials. The average amount of minerals in the diet was 1,074 grams per day, divided as follows:

	Milligrams		*Milligrams*
Aluminum sulphate	55.61	Magnesium sulphate, dried	364.50
Sodium borate	4.27	Manganese sulphate	20.30
Sodium bromide	0.96	Molybdenum sulphide	0.45
Calcium diphosphate	425.55	Nickel sulphate	13.49
Copper sulphate	4.71	Potassium chloride	7.62
Calcium fluoride	2.05	Potassium sulphate	17.82
Potassium iodide	2.61	Strontium carbonate	5.05
Iron oxide brown	44.00	Titanium oxide	0.05
Magnesium chloride	100.00	Zinc sulphate, dried	4.11
		Cobalt acetate	1.00

These minerals were placed in capsules of such size that three capsules contained approximately 1,074 grams of the mixture. These are now being given to patients with fractures or with osteoporosis.

Some of the mineral mixture was furnished to a commercial firm, which added it to the standard laboratory diet in such proportions that, if each rat eats one pound of the food a month, he will eat .012 gram of the minerals a day in addition to the minerals in the standard diet. We estimate that this is equivalent to about three times the amount of the same minerals which we are adding to the diet of our patients with fractures and which the inhabitants of Deaf Smith County consume daily.

MATERIAL AND METHODS

One hundred and thirty male albino rats of the Sprague-Dawley strain were used. These were divided into two groups. Of the first group of thirty rats, fourteen were fed the standard laboratory diet and sixteen were fed the same diet, together with the minerals. (The latter will be referred to as the mineral-fed animals.) They were started on the diets at four weeks of age. At thirteen weeks of age they were anaesthetized with ether, the right femur in each was fractured over the edge of a container, and the fractures were left without fixation. The rats were sacrificed at five, ten, twenty-one, twenty-eight, thirty-five, and sixty days after fracture.

The second group of 100 rats were placed on the same diets when they were four weeks of age, fifty being fed the standard diet and fifty the diet containing the excess minerals. When they were twelve weeks old, each rat was anaesthetized with ether, the skin over the shoulder was shaved and prepared with antiseptic, and through a small skin incision the acromion was lifted to expose the proximal end of the humerus. A small hole was drilled in this and a malleable stainless-steel pin was forced into the medullary canal. The skin was then closed and the humerus was fractured over the edge of a container and straightened, the pin serving to maintain alignment and position of the fragments. These animals were sacrificed with ether in groups of ten at two, four, five, seven, ten, twelve, fourteen, sixteen, eighteen, and twenty-one days.

At postmortem examination both femora and both humeri were amputated and the muscles were removed, care being taken to damage the periosteum and callus of the fractured bones as little as possible. The pins were removed and the fractured bones were tested for union by manipulation and were then fixed in formalin. After roentgenograms of the fractured bones had been made, the bones were decalcified, embedded in paraffin, sec-

FIG. 1

Photomicrograph (× 50) showing section from the humerus of a mineral-fed rat fourteen days after fracture and fixation with a medullary pin. The cartilaginous callus has almost disappeared and the two fragments are beginning to be fused by trabeculae of bone.

tioned and stained, and studied microscopically. The other humerus and both femora were saved for chemical analysis.

OBSERVATIONS

At the start of the experiment the average weight of the fifty control animals in the second group was 63.5 grams, while that of the mineral-fed rats was 61.5 grams. At twelve weeks (before the operation) the average weight of the controls was 305.0 grams, while that of the mineral-fed rats was 333.5 grams. Thus the control animals increased their

FIG. 2

Photomicrograph (× 50) showing section from the humerus of a control rat fourteen days after fracture and fixation with a medullary pin. In this specimen, too, the cartilaginous callus has almost disappeared and the two fragments are beginning to be fused by trabeculae of bone.

weight 4.80 times, while the mineral-fed rats increased their weight 5.42 times during the eight-week period.

In the first group, in which the fractures had not been immobilized, the ends of the fragments were overriding and there was gross deformity of the extremity in all of the fractured limbs.

Of this group union occurred in only one rat, a mineral-fed animal which was sacrificed at sixty days. Five other animals sacrificed at sixty days —two mineral-fed and three control rats —all showed fibrous union. Of the remainder the only difference noted be-

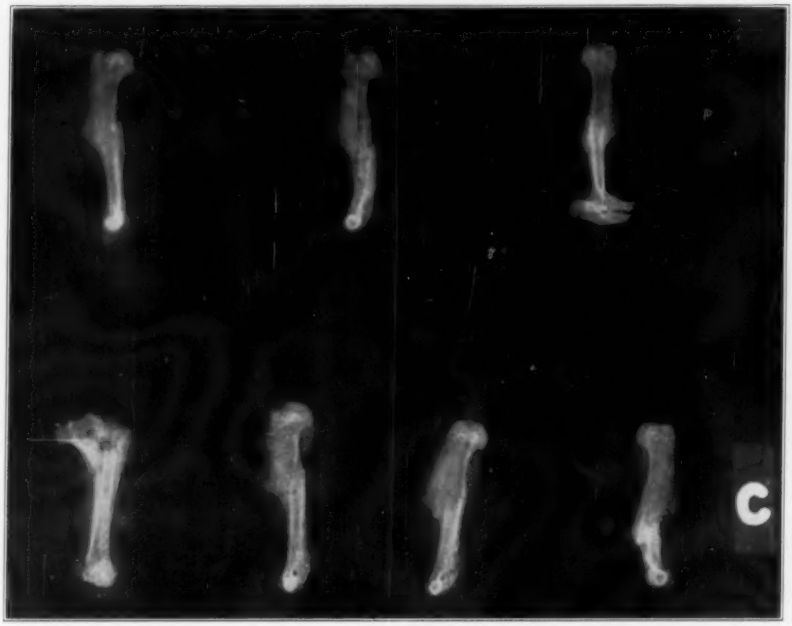

FIG. 3

Roentgenograms of humeri of seven rats twenty-one days after fracture and fixation with a medullary pin. All show solid union by bone. The humeri from mineral-fed rats are shown above, those from the control rats are shown below.

tween the mineral-fed and the control rats was that the callus was definitely larger in the control animals at twenty-one and at thirty-five days. The smaller and firmer callus in these mineral-fed animals suggests that it was maturing slightly more rapidly in these animals than in the controls.

As has been stated, the 100 animals in which the fragments had been immobilized with a medullary pin were divided into ten groups, each containing five control and five mineral-fed rats. In these animals the fragments were united by a firm cartilaginous callus at seven, ten, and twelve days and there was no perceptible difference between the mineral-fed and the control rats.

At fourteen days, three of the mineral-fed rats and one control rat showed clinical evidence of union by bone and the others showed hard, firm callus with slight mobility. At sixteen days, four of the mineral-fed animals had union by bone; in the fifth, in which union was not present, the nail had failed to fix the distal fragment. Of the controls, two had union by bone and two showed slight mobility at the fracture site. Of the rats sacrificed on the eighteenth day, the humerus in one of the mineral-fed animals was fractured below the pin, while the other three had clinical evidence of union. Three of the control rats had solid union and the other two exhibited slight movement at the site of the fracture. In all ten of the animals sacrificed at twenty-one days, the fractures were united by bone.

The roentgenograms of the specimens tended to confirm the clinical impressions and showed lack of union in fractures in which motion was present and bony union in those which were found to be clinically solid.

Likewise, the microscopic examination of sections cut through the fracture sites showed progressively maturing callus in the specimens removed at varying intervals after

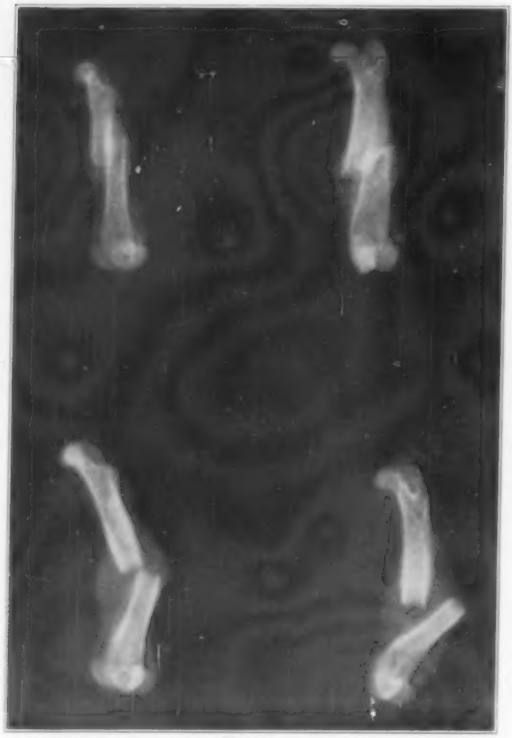

FIG. 4

Roentgenograms of femora of four rats twenty-one days after fracture. No form of immobilization had been applied, and none of the specimens show union. Femora from the mineral-fed rats are shown above, those from the control rats are shown below.

the fracture and tended to confirm the impressions gained by clinical and roentgenographic examination. Furthermore, even in the early specimens, obtained before union could have occurred, we could detect no significant difference between the fractures in the mineral-fed and the control rats. Of those sacrificed at two days the mineral-fed rats showed a thin layer of newly formed membranous bone beneath the periosteum near the fractured end of each fragment; in the same locality in the controls there was a similar layer of membranous bone of approximately the same thickness and apparent age. Likewise at seven days, when the cartilaginous callus was well developed, there was no appreciable difference between the mineral-fed and the control rats. This was also true of the specimens obtained after longer intervals.

Even in the rats sacrificed at fourteen days, in which the callus in the mineral-fed animals seemed to be more mature in that it was smaller and more firm than in the control animals, there was no discernible difference in the microscopic sections of the two groups.

DISCUSSION

Deaf Smith County, Texas, is an area in which the water contains a relatively large amount of fluorine and in which tooth decay occurs less frequently than in any other area of which we have record. The authors had hoped that Barnett's analysis of the minerals ingested by its citizens would give us the long sought formula of a substance which, when added to the diet of patients with fractures, would cause more rapid fracture healing than usual. We had hoped first to obtain proof that the mineral mixture accelerates the healing of fractures, and then to search for the element or combination of elements which was responsible for this desirable result. Unfortunately our hopes have not been realized and in our experimental animals we have not been able to detect any significant difference in the rate or manner of fracture healing between the mineral-fed and the control animals. It is true that union occurred somewhat earlier in more of the mineral-fed animals than in the controls. However, we do not believe that in a study of such a variable process as the healing of a fracture the difference in time of healing is great enough to warrant the conclusion that the addition of excess minerals to the diet accelerated union.

In seeking an explanation of our failure to confirm Barnett's clinical observations, it seems possible that our control animals were on an optimum or nearly optimum mineral

Fig. 6: Roentgenograms of femora of six rats sixty days after fracture. No immobilization had been applied. Femora from the mineral-fed rats are shown above, those from the control rats are shown below. Only one of the mineral-fed rats had union. Comparison with Fig. 3 demonstrates the importance of immobilization in fracture healing.

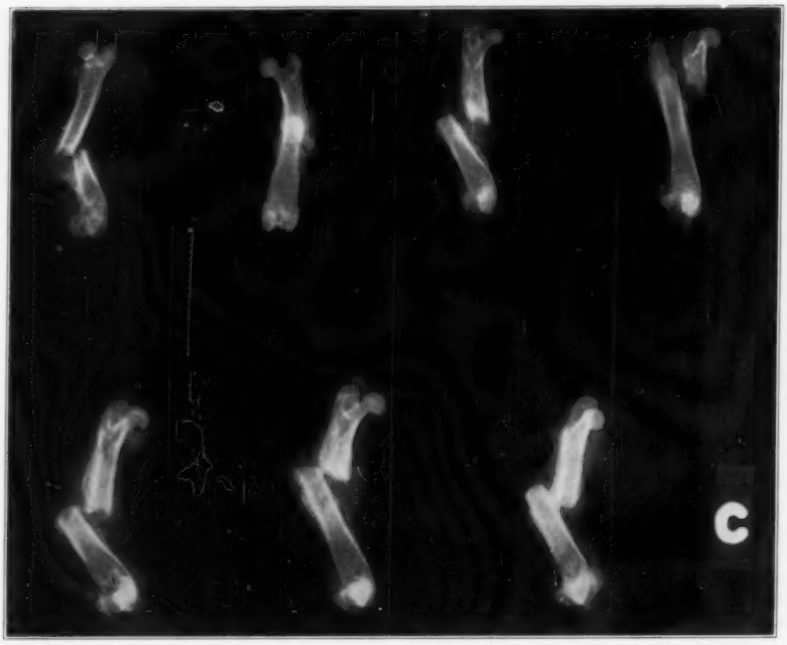

FIG. 5

Roentgenograms of femora of seven rats twenty-nine days after fracture. No immobilization had been applied and none of the specimens showed union. Femora from the mineral-fed rats are shown above, those from the control rats are shown below.

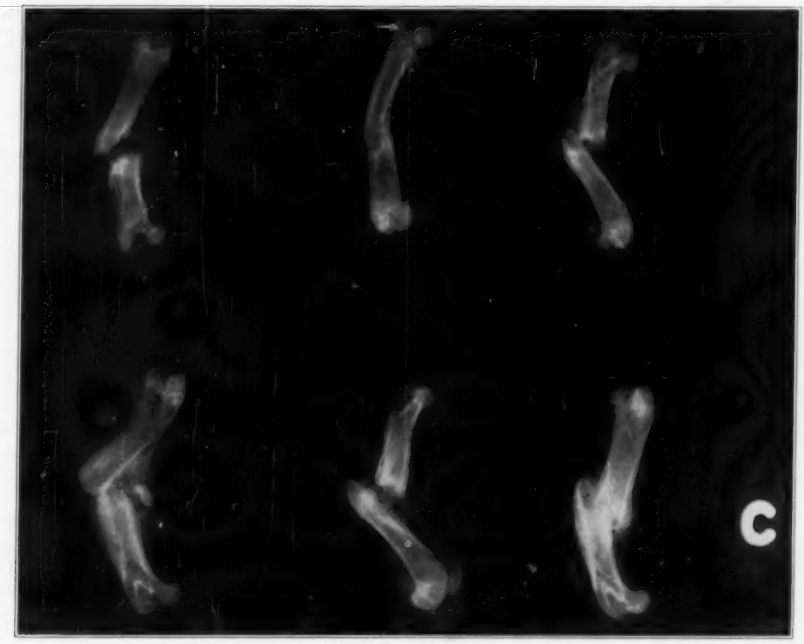

FIG. 6

intake and that little could be done to improve it. This is not necessarily true of human patients, because the average person who suffers a fracture may be on an adequate, but considerably less than optimum, mineral intake. In addition to 25 per cent. protein, 6 per cent. fat, and many minerals, the standard diet used for laboratory animals contains 1.3 per cent. calcium. Sherman and Booher found that 0.2 per cent. was sufficient for maintenance and considered 0.5 to 0.8 per cent. to be sufficient for optimum nutrition. On the other hand, the addition of minerals to the diet resulted in an increase in weight in the experimental animals which was 9.6 per cent. greater than that of the control animals, even though the latter were on an unusually high mineral intake, and we believe this to be of some significance. Finally, we have not been able to detect any harmful effects which could be attributed to the feeding of the excess minerals to rats.

Apposition and immobilization still appear to be the most important factors in the union of fractures.

NOTE: The mineral mixture used in these experiments was furnished by the Upjohn Company, Kalamazoo, Michigan, and the diet containing the mixture was prepared by the Ralston Purina Company.

REFERENCES

1. BARNETT, L. B.: New Concepts in Bone Healing. (Unpublished paper read before the Texas Orthopaedic Association, Dallas, Texas, May 5, 1952.)
2. FISCHER, FREDERICK, and KEY, J. A.: Local Atrophy of Bone. III. Effects of Vitamin D and of Calcium on Local Atrophy and Union. Arch. Surg., **29**: 312–315, 1934.
3. KEY, J. A.: Local Bone Atrophy. Am. J. Roentgenol., **30**: 34–39, 1933.
4. ODELL, R. T., and KEY, J. A.: The Effect of Chronic Fluorine Intoxication upon the Healing of Experimental Fractures in Rats. Ann. Surg., **138**: 461–466, 1953.
5. SHERMAN, H. C.: Chemistry of Food and Nutrition. Ed. 7, p. 226. New York, Macmillan, 1946.
6. SHERMAN, H. C., and CAMPBELL, H. L.: Growth and Reproduction upon Simplified Food Supply. IV. Improvement in Nutrition Resulting from an Increased Proportion of Milk in the Diet. J. Biol. Chem., **60**: 5–15, 1924.
7. SHERMAN, H. C., and BOOHER, L. E.: The Calcium Content of the Body in Relation to That of the Food. J. Biol. Chem., **93**: 93–103, 1931.

DISCUSSION

DR. JOHN J. FAHEY, CHICAGO, ILLINOIS: In an attempt to explain the difference in healing time of trochanteric fractures among the inhabitants of Deaf Smith County, Texas, and those in Dallas, as reported by Dr. Barnett, Dr. Key and Dr. Odell approached the problem by studying the influence of excess minerals on experimentally produced fractures in the rat. This mineral intake is one of the most probable variables, and the one which Dr. Barnett thought was responsible for the accelerated rate of healing. Even though it appeared unlikely that a considerable difference in healing time would be observed, Dr. Key and Dr. Odell rightly wished to investigate any possible method of accelerating bone healing.

They fed a control group of rats an optimum mineral diet and a second group an optimum mineral diet to which was added three times the amount of minerals consumed by the residents of Deaf Smith County, in whom fracture healing is supposedly rapid. They found no evidence that the excess mineral intake influenced fracture healing. However, they observed a significant weight gain in the group fed the excess minerals.

The authors did not attempt to exclude other factors, such as the administration of the minerals over an extended period of time, or the possible excess of one or more individual mineral compounds in a more favorable ratio to determine whether or not a beneficial influence was exerted.

Dr. Barnett believed that magnesium was the most probable factor responsible for the rapid healing, since the bone ash of the residents of Deaf Smith County contained 1.6 per cent. of magnesium—almost four times the amount found in the Dallas residents. The food intake of the Dallas residents could not be analyzed accurately, so that the total mineral intake in the two regions could not be compared. A comparison of the mineral content in the bone ash from both areas and the known composition of both the water and the food of the group with rapid healing was the chief basis for the assumption that there was a high mineral content.

If Dr. Key and Dr. Odell should observe changes in the x-rays which would indicate less osteoporosis and accelerated healing time of fractures in the inhabitants of Deaf Smith County, it would seem advisable to continue this investigative work, with use of more specific eliminating diets. It is believed by some that absorption of magnesium is diminished by an excessive intake of phosphates, as well as of fat, calcium, and other alkalies.

It will be interesting to hear from Dr. Key and Dr. Odell whether they have observed any stimulation of healing in their patients, who are receiving the same ratio of minerals as the residents of Deaf Smith County.

OSTEOSYNTHESIS WITH BLOUNT'S STAPLES IN FRACTURES OF THE PROXIMAL END OF THE HUMERUS

A Preliminary Report

BY F. TEJERA LORENZO, M.D., HAVANA, CUBA

From the Instituto de Cirugia Ortopedica, Habana

In the past, when performing open reductions with internal fixation of fractures of the proximal end of the humerus, we have used Vitallium nails and screws. The fixation thus obtained was sometimes quite inadequate, necessitating prolonged immobilization with the frequent development of a frozen shoulder. In contrast to this, since we have used Blount's staples for fixation, the time of immobilization has been shortened and we have obtained more secure fixation. We have employed this method since 1952 with encouraging results. A review of the literature has revealed no reference to this method.

Needless to say, this method of treatment is employed only where conservative methods have failed. Our operative findings in these cases have shown that either the edge of one fragment is protruding through a buttonhole slit in the capsule of the shoulder, or the long head of the biceps tendon is lying between the fragments, or both conditions coexist, making manipulative reduction impossible.

In children, injury to the epiphyseal plate must be avoided. We have found it possible to make use of the long triangular piece of metaphysis which is nearly always attached to the proximal fragment in adduction fractures. This can be fixed to the shaft by means of the staple. In one case we feared that penetration of the staple into the epiphyseal

Fig. 1-A

Fig. 1-B

Fig. 1-A: Case 1. O. H. Roentgenogram made June 2, 1952, showing malposition of the fragments.
Fig. 1-B: Roentgenogram made September 10, 1953, fifteen months after surgery.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. M. F. Roentgenogram made at the time of the injury, January 2, 1953.

Fig. 2-B: Roentgenogram made August 13, 1953. Note the overgrowth of callus along the humeral shaft.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 3. J. M. Roentgenogram made at the time of the injury, July 24, 1953.

Fig. 3-B: Roentgenogram made August 15, 1953, eighteen days after reduction. Perfect reduction had been obtained without immobilization.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 4. F. G. Roentgenogram made at the time of the injury, August 11, 1953.
Fig. 4-B: Roentgenogram made two months after reduction, October 24, 1953.

plate might cause damage resulting in either deformity or retardation of growth. However, roentgenograms made sixteen months after surgery showed closure of the epiphyseal plate, as might have been expected with any form of treatment. The measurement from the acromion to the tip of the olecranon was 30.5 centimeters in both arms. Although retardation of growth will result, a difference of two or three centimeters in length in the upper extremity is not ordinarily of significance.

TECHNIQUE

Under general anaesthesia an anterior deltoid incision is made, extending from the coracoid process at the lower margin of the clavicle downward along the anterior margin of the deltoid muscle as far as is necessary for exposure. A portion of the anterior fibers of the deltoid muscle is separated from the clavicle and is retracted laterally. The shaft of the humerus is found to lie anteriorly and protrudes through a buttonhole tear in the capsule of the shoulder joint. The long head of the biceps tendon is found under the anterior edge of the distal fragment. The proximal fragment lies in the position of external rotation. After the fracture surfaces have been cleared of blood clots, reduction and fixation are performed. The wound is closed in the routine manner. With regard to inserting the staples, it should be emphasized that in the adolescent the two points of the staple will penetrate the cortex simultaneously and symmetrically. However, in the adult, in whom the cortex of the distal fragment is harder than that of the proximal, the distal cortex should be perforated first, so that the staple may then be driven in symmetrically.

At the conclusion of the operation, the limb is immobilized by a Campbell traction humerus splint which can be applied while the patient is still under general anaesthesia. This immobilization is continued for approximately twenty-five days, after which the splint is replaced by a sling. Active movements, except for abduction, are instituted at this time. One week later active abduction is begun. All the patients who have been treated by this method returned to their original occupation two months after surgery.

With the exception of a little girl, who returned to school, all were farmers and engaged in heavy labor. In no instance has it been necessary to remove the staples nor has it been necessary to employ physical therapy to regain shoulder motion.

CASE REPORTS

Case 1. O. H., a girl, aged thirteen. Roentgenographic examination made at the Hospital on admission revealed a fracture through the proximal epiphyseal line of the humerus (Fig. 1-A), a portion of the metaphysis remaining attached to the humeral head. Several attempts to reduce the fracture by manipulation were unsuccessful.

On June 10, 1952, one week after the injury, operative reduction was accomplished. The patient was followed for a period of several months. Roentgenograms (Fig. 1-B) made fifteen months after the reduction showed excellent alignment of the fragments and solid union. The patient had normal limb length and complete recovery of function.

Case 2. M. F., a man, aged twenty-eight. Roentgenograms (Fig. 2-A) made at the time of admission revealed an unimpacted abduction fracture with marked angulation.

On January 7, 1953, five days after the injury, operative reduction was accomplished. Roentgenograms (Fig. 2-B) made seven months after reduction showed an overgrowth of callus along the humeral shaft, but abduction was normal.

Case 3. J. M., aged eighteen. Roentgenographic examination made at the time of admission to the Hospital revealed epiphyseal separation of the head of the humerus (Fig. 3-A).

On July 28, 1953, four days after the injury, and after two attempts at manipulative reduction had failed, operation was performed. Roentgenograms made eighteen days after open reduction showed that perfect position had been maintained, even though no external immobilization was used (Fig. 3-B). Complete function was regained rapidly.

Case 4. F. G., a man, aged fifty-eight. Roentgenograms made at the time of admission revealed a fracture of the anatomical neck of the humerus (Fig. 4-A).

On August 15, 1953, four days after the injury, operative reduction was performed. A roentgenogram made October 24, 1953 (Fig. 4-B), showed good reduction. Recovery of function was complete.

DISCUSSION

Residual Deformities of the Shoulder

(*Continued from page 36*)

I believe this is a worth-while paper and I should like to thank Dr. Wickstrom for renewing interest in a proceduce which has perhaps been somewhat neglected in recent years.

Dr. Haslam (closing): We would like to thank Dr. Badgley and Dr. Outland for their very thoughtful and profitable discussion of this report. There are several points which I think we might emphasize. While we have, of course, obtained our best results with patients who had fairly good function of the forearm and hand, we have been surprised on occasion to find that, once we have corrected the internal-rotation deformity and brought the hand into a position where it can be used, our preoperative evaluation of the forearm and hand had been too pessimistic and that the condition was actually more favorable than we expected. This has led us to be more enthusiastic than we formerly were about the procedure in cases in which the forearm was also involved. I believe it is also important to emphasize that the proper surgical procedure should be selected on the basis of the position of the humeral head and its contour. We also feel that in certain patients the increased operative time and technical difficulties of the L'Episcopo procedure are well justified.

CHRONIC COCCIDIOIDAL SYNOVITIS OF THE KNEE JOINT*

BY FEDERICO SOTELO-ORTIZ, M.D., HERMOSILLO, SONORA, MEXICO

Coccidioidomycosis is an infection caused by the fungus *Coccidioides immitis*. The disease was first recognized in 1892 in Buenos Aires by Posadas and by Wernicke, and subsequently cases were described in California in 1894 by Rixford. The organism was identified as a fungus and cultured by Ophüls and Moffit in 1900.

The disease is endemic in Southern California and Arizona, where the climate is characterized by long, hot, dry, dusty summers and a low annual rainfall. Recently it has been reported in the northwestern part of Mexico.[18] During World War II many troops stationed in endemic regions contracted this infection. The disease resembles tuberculosis and may indeed be confused with it, both histologically and clinically. The site of primary infection is usually the lungs, but occasionally the point of entrance is the skin or possibly the tonsils; in the latter case cervical adenitis results. Primary coccidioidomycosis, the so-called "Valley fever", "Desert fever", or "San Joaquin Valley fever", is an acute, usually benign, pulmonary infection. It is characterized by malaise, anorexia, chills, fever, headache, night sweats, and pleurisy. Roentgenograms show hilar or peribronchial thickening and pneumonitis, and the larger lesions show actual cavitation. The cavities as a rule heal in a few weeks or months, but occasionally persist. Recovery is usually rapid and complete. A primary infection confers immunity on the host in a manner similar to that produced by a primary tuberculous infection. However, an occasional case may pass into the progressive virulent type, with widespread involvement. In the soft tissues, abscesses are formed which in the paravertebral region become calcified. Any or all organs may be involved, with the notable exception of the digestive tract. The bones become infected by direct extension from soft-tissue lesions or by hematogenous spread, presenting a picture similar to tuberculous or pyogenic osteomyelitis. The short bones of the hands and feet, the spine, ribs, scapulae, and clavicles are most commonly involved. Arthritis, the so-called "desert rheumatism", occurs in one third of all primary cases. It is characterized by pain, tenderness, and slight swelling without effusion. The symptoms usually subside within a month without apparent residue. In the disseminated form of the disease, on the other hand, joint involvement is characterized by redness, swelling, fluctuation, ulceration, and not infrequently by sinus formation.

Dissemination, if it is going to occur, usually takes place within the first few weeks or months. This complication should be suspected in the presence of prolonged high fever or symptoms and signs indicative of meningeal, skeletal, or cutaneous involvement. Reactivation of the disease after a period of years and subsequent dissemination from an endogenous source are extremely rare, if they occur at all.

The fungus has been isolated in the sputum of patients with a primary infection, while in the progressive form of the disease it has been found in the sputum, subcutaneous abscesses, and other lesions. In endemic areas it has also been isolated from rodents and from the soil. In the tissues it multiplies by endosporulation.

The organism is a sporule with a thick hyaline capsule. Each sporule is eleven to seventy micra in diameter and contains ten to 200 endospores. When cultured on Sabouraud's medium, the endospores germinate, producing mycelia. All strains contain identical antigens. During the course of a primary infection, precipitins and complement-fixing antibodies develop in the serum, and skin sensitivity to coccidioidin develops. The former antibodies disappear after recovery, but the skin sensitivity, as in tuberculosis, is relatively permanent.

* Read at the Third Annual Alumni Conference of the Hospital for Joint Diseases, New York, N. Y., October 28, 1950.

FIG. 1-A FIG. 1-B

Case 1. Anteroposterior and lateral roentgenograms, made in 1944, of the left knee showing a small focus of osteolysis at the level of the base of the tibial spine and in the margins of the tibial condyles.

The coccidioidin test is of great value in the diagnosis of this infection. Sweigert, Turner, and Gillespie used it in a dilution of 1 to 100, although they did not administer it to patients with skin lesions resembling erythema nodosum. Such skin lesions develop in about 20 per cent. of all cases between the fifth and fourteenth days and persist for one to two weeks. Patients with these lesions were found to be hypersensitive to coccidioidin, and violent local and even systemic reactions developed in some of them. The test may be negative in an early primary coccidioidal infection. This should not be interpreted as excluding the disease, at least until the test has been repeated, since sensitivity to coccidioidin does not develop until seven to fourteen days after onset. An initial negative test followed by subsequent positive tests is almost conclusive evidence of coccidioidal infection. However, in disseminated coccidioidomycosis the test may be negative.

Bone lesions are found only in the disseminated form of the disease. They are primarily destructive, involving bone and cartilage, and are usually multiple. There appears to be a predilection for cancellous bone, as the lesions occur commonly in the vertebral bodies, in the pelvis, and in the ends of the long bones. Involvement of the shafts of the long bones does not occur, except by direct extension from adjacent lesions. However, in the short tubular bones such as the phalanges, primary shaft lesions have been noted.[72] Primary localization occurred in both the metaphysis and the epiphysis. The epiphyseal cartilage, when present, offers no barrier to the spread of the infection.

Joint involvement occurs by direct extension through bone and articular cartilage from adjacent lesions. Primary involvement of joints is rare[4]. A special predilection for bony prominences such as the tibial tubercle, the malleoli, the humeral condyles, the

olecranon process, and the radial styloid is characteristic. In fact, the presence of destructive lesions in these regions is highly suggestive of coccidioidal infection.

The roentgenographic appearance of the bone lesions varies with the stage of the disease. In the acute phase, they are primarily destructive with hazy outlines and little surrounding bone reaction or overlying periosteitis. Sequestration is rare. In the later stages the more common picture of bone proliferation with overlying periosteitis is seen.

The periosteitis if present is of some diagnostic value, since it is seldom seen in tuberculosis, except in the rare shaft lesions. Furthermore, it is less extensive in coccidioidomycosis than in chronic pyogenic osteomyelitis. Cystlike cavities somewhat resembling a bone cyst may develop, but cortical expansion is seen rarely. As healing occurs, bony sclerosis becomes apparent, but this is never as marked as that seen in chronic pyogenic osteomyelitis.

Fig. 1-C: Lateral roentgenogram, made November 15, 1949, of the left knee, showing two large cavities in the posterior aspect of the medial femoral condyle.

Fig. 1-C

Fig. 1-D: Photomicrograph (× 325) showing a typical coccidioidal "tubercle" with a spherule in the center.

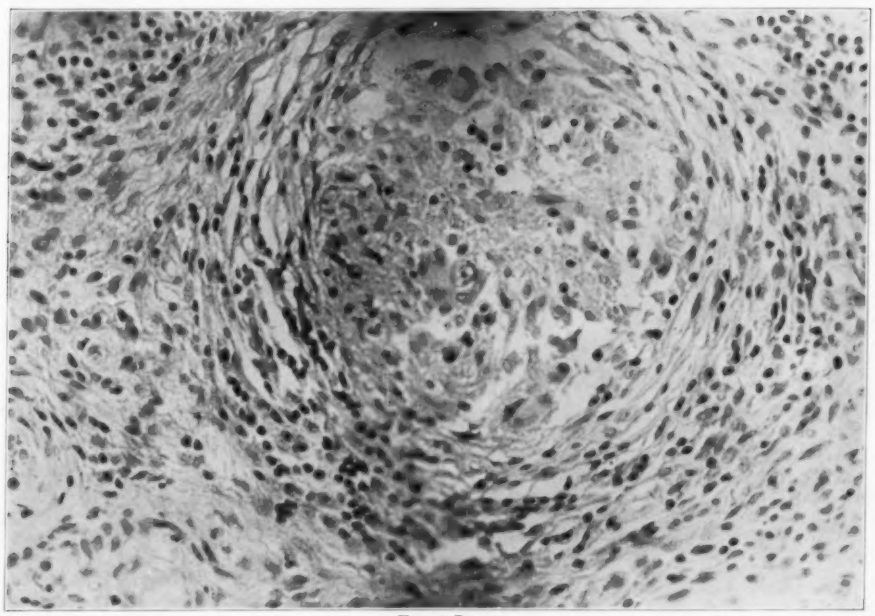

Fig. 1-D

FIG. 2-A FIG. 2-B

Case 2. Anteroposterior and lateral roentgenograms of the right knee. No bone changes are evident. There is thickening of the synovial membrane, mainly in the popliteal space.

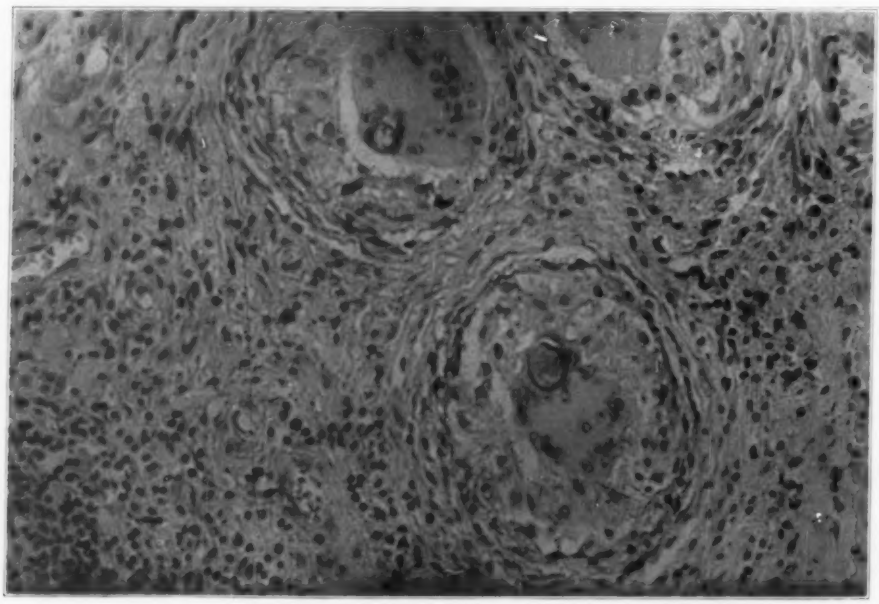

FIG. 2-C

Low-power photomicrograph (× 325) showing several coccidioidal "tubercles", in each of two of which a central Langhans cell is engulfing a spherule.

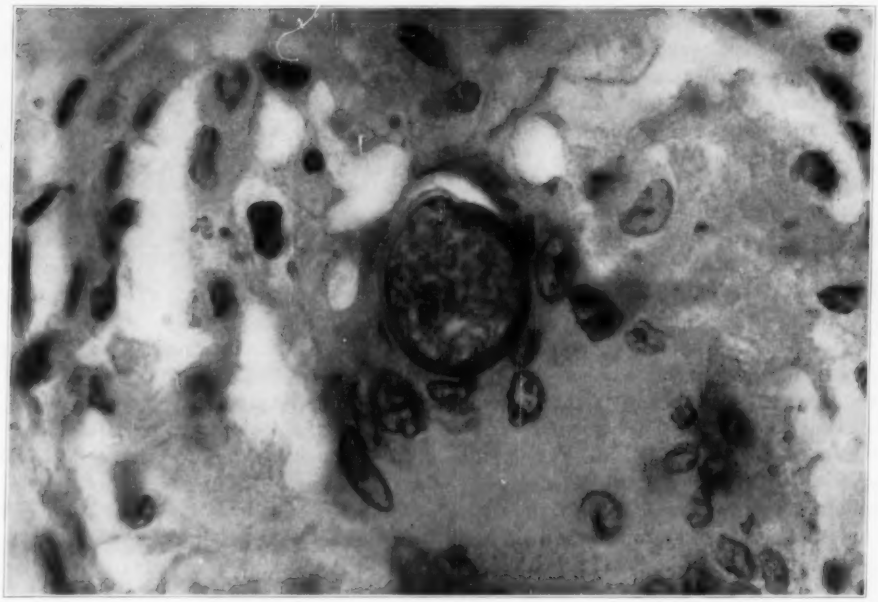

FIG. 2-D

Photomicrograph (× 1250) showing spherules of *Coccidioides immitis*. The double refractile capsule is clearly visible. This is a high-power view of the tubercle shown in Fig. 2-C.

In this condition, as in tuberculosis, the vertebral body is usually affected if there is involvement of the spine, although occasionally the initial focus is found in the neural arch or the spinous process. In the vertebral bodies the lesion may be central, causing first localized decalcification, then destruction, and finally collapse, or it may be peripheral, causing cortical erosion. The intervertebral cartilage is not destroyed as rapidly in coccidioidal spondylitis as in tuberculosis. The lesions tend to remain localized longer and to perforate the cortex, forming paravertebral abscesses. However, in long-standing cases the intervertebral disc may be destroyed and bony ankylosis may follow if the patient survives.

In the skull both tables are involved, the defect usually being larger in the outer table. The lesions appear as small, circumscribed, punched-out areas of destruction.

In flat bones, such as the sternum and the scapulae, bone destruction occurs, usually associated with overlying soft-tissue swelling.

Joints may be involved secondarily by direct extension from an osseous lesion; this leads to narrowing of the joint space, destruction of the joint, and ankylosis, if the patient survives. In primary joint infections only the synovial membrane may be involved, in which case only capsular thickening or fluid is apparent in the roentgenograms. With progression of the synovial infection, marginal joint destruction, resembling that seen in tuberculous synovitis, occurs, followed by destruction of the joint. However, in coccidioidal arthritis the regional bone atrophy is not so marked as in the latter infection.

In acute cases the bone lesions are characterized by necrosis and abscess formation with little if any bony proliferation. The cortex may be more or less destroyed and there may be an associated soft-tissue abscess. The periosteum may appear oedematous and thickened or it may be partly destroyed. In long-standing or chronic lesions there may be an abscess or a cavity filled with granulation tissue, or the spongiosa may be permeated with grayish granulation tissue. Bone "sand" or, occasionally, bony sequestra may be

found in the necrotic tissue. The surrounding bone may be hyperaemic or sclerotic. Overlying cortex may be more or less destroyed. The surrounding periosteum is thickened and subperiosteal ossification may be present.

Microscopically the acute bone lesions are characterized by necrosis, abscess formation, and osteoclastic bone destruction with little, if any, new-bone formation. Coccidioidal spherules may be visible. In the chronic lesions — the type usually seen — an abscess and granulation tissue are found. The latter contains primarily round cells, but polymorphonuclear leukocytes, histiocytes, giant cells, coccidioidal spherules, and occasionally quite typical "tubercles" are also found. The spherules have a double refractile capsule and contain numerous endospores. They are found either free or within tubercles or giant cells (Fig. 2-D). They are not to be found in every microscopic field and must be searched for. If they are not found, a positive diagnosis cannot be made.

Partly or completely necrotic bone fragments are typical. These and other bony trabeculae present serrated margins, with osteoclasts in the lacunae.

Infected joints exhibit a thickened, grayish synovial membrane and serous or seropurulent joint fluid. The articular cartilage is thinned and segments of cartilage may separate from the underlying bone. Pannus formation is present, producing marginal erosion. Microscopically, the same type of process occurs here as in the bone lesions. Spherules can also be identified, either free, within the tubercles, or in the giant cells. Direct extension of granulation tissue from the synovial lining produces marginal erosion of the articular cartilage and subchondral bone with the formation of a pannus.

The prognosis in coccidioidomycosis is excellent in the primary pulmonary form, good in the dermal or glandular types when they represent a primary infection, and extremely unfavorable in the generalized form or in cases with meningeal involvement.

No specific therapy is available. The sulfonamides and penicillin are ineffective except to combat secondary infection. Potassium iodide and vaccine therapy have produced disappointing results. Jacobson[10] used colloidal copper supplemented with injections of coccidioidin with good results. Arnold and Levy unsuccessfully treated a case with generalized involvement with intrathecal and intramuscular penicillin in massive doses. In general treatment of the disseminated form of the disease has been unsuccessful.

CASE REPORTS

Case 1. G. C., a white female, thirty-two years old, was first seen on August 15, 1949. Nine years before, she had first noted pain and swelling of the left knee joint, mainly after exercise. These symptoms had gradually become worse.

Physical examination showed a considerably thickened synovial membrane and some effusion in the left knee joint. There was some limitation of knee flexion. The right knee measured thirty-four centimeters in circumference; the left knee 36.5 centimeters. Routine laboratory examinations were not contributory. A coccidioidin test was not done. Anteroposterior and lateral roentgenograms (Figs. 1-A and 1-B) made elsewhere in 1944 and brought in by the patient showed small foci of osteolysis at the base of the tibial spine and in the anterior margins of the medial and lateral condyles of the tibia. A mass was palpable in the popliteal region which represented thickening of the synovial membrane of the posterior compartment of the knee. A chest roentgenogram was negative for pulmonary invasion.

The knee was aspirated on September 6, 1949, and about fifty cubic centimeters of transparent yellowish fluid was withdrawn.

Roentgenograms made by the author on September 9, 1949, showed no change in the appearance of the lesions of the tibia. In the posterior aspect of the medial femoral condyle two large cavities could be seen, with a tendency to show trabeculation or a multilocular appearance (Pomeranz).

A tentative diagnosis of pigmented villonodular synovitis was made.

On September 13, 1949, an exploratory arthrotomy was performed under tourniquet through a medial parapatellar incision. Some remaining fluid was evacuated. The synovial membrane was found to be considerably thickened, measuring two centimeters in thickness in the suprapatellar and parapatellar pouches. The membrane was shiny and white or yellowish in some areas, while in others it was bluish or purplish, apparently ecchymotic. There were many villi, some thick and sessile, others pedunculated. These had invaded both aspects of the menisci.

A synovectomy was performed; this did not include the posterior compartment. Gross examination revealed that the lesion was neither pigmented villonodular synovitis nor tuberculosis.

A well padded compression bandage was applied and at the end of ten days the stitches were removed.

The wound healed by primary intention. Early but slow motion of the knee was permitted, as well as weight-bearing, as much as the patient could stand. The histological specimen was sent to Dr. Louis Lichtenstein of Los Angeles, and his report of October 4, 1949, was as follows: "The general background of the lesion is that of a chronic villous synovitis but within the inflamed synovium there are a few granulomatous nodules, one of which contains a spherule with a doubly refractile capsule that stamps the lesion as one of coccidioidomycosis" (Fig. 1-D). Roentgenograms made on November 15, 1949 (Fig. 1-C), showed no change from the previous roentgenograms.

On October 12, 1950, the patient was examined again. The synovial membrane had become considerably thickened since operation. The patella was freely movable. She was still having some pain, but not as severe as before operation. There was some loss of motion of the joint, with flexion to 95 degrees and extension to 180 degrees. The circumference of the left knee was thirty-five centimeters; that of the right knee was thirty-four centimeters.

Case 2. J. S., a white male, nineteen years old, was first seen in May 1950. He stated that in 1947, after jumping off a truck and twisting his right knee, he began to have pain in the right knee, which was aggravated by exercise. He also noticed the growth of a lump deep in the popliteal region and progressive swelling of the knee. Slowly flexion became limited. Two years before he was seen, an acute abscess had developed on the anteromedial aspect of the medial tibial condyle and drained yellowish pus. Drainage persisted for about a month, after which spontaneous healing occurred.

Physical examination showed considerable thickening of the synovial membrane and some effusion in the joint. A mass about the size of half an orange was palpable deep in the popliteal region.

Flexion of the knee was limited to 45 degrees, while extension was 180 degrees. Laboratory findings were non-contributory. A coccidioidin test was not done.

Roentgenograms made on May 19, 1950 (Figs. 2-A and 2-B), showed considerable thickening of the synovial membrane, amounting to about three centimeters in the suprapatellar pouch, as well as a soft-tissue mass about the size of half an orange in the popliteal region, apparently due to thickening of the synovial membrane of the posterior compartment of the joint.

A chest roentgenogram was negative for pulmonary invasion.

On May 26, 1950, through a medial parapatellar incision, an exploratory arthrotomy was performed under tourniquet. The appearance of the joint and of the synovial membrane was essentially the same as that found in the preceding case. A synovectomy was performed which did not include the posterior compartment. The specimen was sent to Dr. Lichtenstein and his diagnosis in this case also was coccidioidomycosis of the synovial membrane of the knee joint (Figs. 2-C and 2-D).

The postoperative course of this patient was similar to that of the first. Although he had lost some flexion of the joint, it was not felt advisable to attempt to increase it, because of the hazard of a flare-up or spread of the infection.

Re-examination on October 12, 1950, showed flexion to 95 degrees and extension to 180 degrees, and the patient had no complaints.

DISCUSSION

A review of the literature [1-43] indicates that very little has been written concerning chronic synovitis of coccidioidal origin. This disease may be confused with tuberculosis, particularly in parts of the country where coccidioidomycosis is uncommon. Furthermore, as the result of wartime exposure and rapid modern transportation, it seems probable that it will be seen more frequently in regions where its presence will not be suspected. The two cases of chronic synovitis due to coccidioidomycosis reported here serve to illustrate the difficulties in the diagnosis and treatment of this rare condition.

Note: Since the presentation of this paper a new drug has been added to the therapy for this condition: ethyl 4-hydroxy-3-methoxybenzoate (Ethyl vanillate Squibb), supplied in capsules of 0.5 gram and as a crystalline powder. This was developed as a by-product in the manufacture of sulphite pulp in the course of a research program on waste disposal in the paper industry. Treatment usually requires long periods of time, often several months.

REFERENCES

1. Arnold, W. T., and Levy, M. D.: Coccidioidomycosis Treated with Penicillin. Southern Med. J., **39:** 609–613, 1946.
2. Benninghoven, C. D., and Miller, E. R.: Coccidioidal Infection in Bone. Radiology, **38:** 663–666, 1942.
3. Burks, J. W., and Thompson, P. E.: Coccidioidomycosis. Southern Med. J., **39:** 613–619, 1946.
4. Carter, R. A.: Infectious Granulomas of Bones and Joints, with Special Reference to Coccidioidal Granuloma. Radiology, **23:** 1–16, 1934.
5. Culiner, N. W.: Clinical Aspects of Coccidioidomycosis. Bull. New England Med. Center, **6:** 238–246, 1944.

6. Davis, B. L., Jr.; Smith, R. T.; and Smith, C. E.: An Epidemic of Coccidioidal Infection (Coccidioidomycosis). J. Am. Med. Assn., **118:** 1182–1186, 1942.
7. Good, G. A.: Roentgenological Manifestations of Coccidioidomycosis. Proc. Staff Meet. Mayo Clin., **22:** 341–345, 1947.
8. Goren, M. L.: Localized Coccidioidomycosis of Bone. Report of a Case. J. Bone and Joint Surg., **28:** 157–160, Jan. 1946.
9. Haynes, D. M., and Hess, W. I.: Cutaneous Test with Coccidioidin. Review of the Literature and Report of a Series in Texas. J. Lab. and Clin. Med., **31:** 1317–1324, 1946.
10. Jacobson, H. P.: Immunotherapy for Coccidioidal Granuloma. Arch. Dermatol. and Syphilol., **40:** 521–540, 1939.
11. Jacobson, H. P.: Coccidioidomycosis. Arch. Dermatol. and Syphilol., **57:** 561–564, 1948.
12. Jaffe, H. L.: Personal communication, October 1950.
13. Jamison, H. W., and Carter, R. A.: The Roentgen Findings in Early Coccidioidomycosis. Radiology, **48:** 323–332, 1947.
14. Lamphier, T. A.: Localized Coccidioidal Osteomyelitis. New England J. Med., **238:** 150–152, 1948.
15. Madrid, G. S.: Coccidioidosis. Prensa Méd. (Hermosillo), **6:** 1033–1035, 1946.
16. Madrid, G. S.: Las micosis pulmonares. 1ª. Parte. Rev. Mexicana de Tuberculosis y Aparato Respiratorio, **9:** 32–55, 1948.
17. Madrid, G. S.: Las micosis pulmonares. 2ª. Parte. Rev. Mexicana de Tuberculosis y Aparato Respiratorio, **9:** 88–111, 1948.
18. Madrid, G. S.: Coccidioidomicosis en el Estado de Sonora (México). Prensa Méd. (Hermosillo), **10:** 2–17, 1950.
19. Madrid, G. S.: La resección pulmonar en el tratamiento de la coccidioidomicosis. Prensa Méd. (Hermosillo), **10:** 2–11, 1950.
20. Madrid, G. S.: Cáncer y coccidioidosis pulmonar. Prensa Méd. (Hermosillo), **11:** 20–22, 1951.
21. Madrid, G. S.: Personal communication, August 1953.
22. McMaster, P. E., and Gilfillan, Charles: Coccidioidal Osteomyelitis. J. Am. Med. Assn., **112:** 1233–1237, 1939.
23. Ophüls, Wilhelm, and Moffit, H. C.: A New Pathogenic Mould (Formerly described as a protozoon, Coccidioides immitis pyogenes). Preliminary Report. Philadelphia Med. J., **5:** 1471, 1900.
24. Pomeranz, M. L.: Personal communication, October 1950.
25. Posadas, A.: Un nuevo caso de micosis fungoidea con Psorospermias. Ann. Cir. Med. Argentine, **15:** 535, 1892.
26. Quill, L. M., and Burch, J. C.: Surgical Manifestations of Coccidioidomycosis. Ann. Surg., **120:** 670–679, 1944.
27. Rixford, E.: A Case of Protozoic Dermatitis. Occidental Med. Times, **8:** 704, 1894.
28. Rixford, E., and Gilchrist, T. C.: Two Cases of Protozoan (Coccidioidal) Infection of the Skin. Rep. Johns Hopkins Hosp., **1:** 209, 1896.
29. Rosenberg, E. F., Dockerty, M. B.; and Meyerding, H. W.: Coccidioidal Arthritis. Report of a Case in Which the Ankles Were Involved and the Condition Was Unaffected by Sulfanilamide and Roentgen Therapy. Arch. Int. Med., **69:** 238–250, 717, 1942.
30. Rosenthal, S. R.: Contagiousness of Coccidioidomycosis. (Abstract.) J. Lab. and Clin. Med., **32:** 1535, 1947.
31. Sashin, D.: Coccidioidomycosis with Involvement of Bone. Bull. Hosp. Joint Dis., **8:** 59–68, 1947.
32. Sashin, D.; Brown, G. N.; Laffer, N. C.; and McDowell, H. C.: Disseminated Coccidioidomycosis Localized in Bone. Am. J. Med. Sciences, **212:** 565–573, 1946.
33. Smith, C. E.: Coccidioidal Granuloma. Roentgen Diagnosis. Am. J. Roentgenol., **25:** 715–738, 1931.
34. Smith, C. E.: An Epidemiological Study of Acute Coccidioidomycosis with Erythema Nodosum. *In* Proceedings of the Sixth Pacific Science Congress, 1939. Vol. V, pp. 797–809, 1939.
35. Smith, C. E.: Parallelism of Coccidioidal and Tuberculous Infections. Radiology, **38:** 643–648, 1942.
36. Smith, C. E.: Coccidiosis-Coccidioidomycosis. (Editorial.) Radiology, **39:** 486–487, 1942.
37. Smith, C. E.: Coccidioidomycosis. Med. Clin. North America, **27:** 790–807, 1943.
38. Smith, C. E.; Beard, R. R.; Rosenberger, H. G.; and Whiting, E. G.: Effect of Season and Dust Control on Coccidioidomycosis. J. Am. Med. Assn., **132:** 833–838, 1946.
39. Smith, C. E.; Beard, R. R.; Whiting, E. G.; and Rosenberger, H. G.: Varieties of Coccidioidal Infection in Relation to Epidemiology and Control of Diseases. Am. J. Pub. Health, **39:** 1394–1401, 1946.
40. Smith, C. E.; Beard, R. R.; and Saito, M. T.: Pathogenesis of Coccidioidomycosis with Special Reference to Pulmonary Cavitation. Ann. Int. Med., **29:** 623–655, 1948.
41. Smith, C. E.; Saito, M. T.; Beard, R. R.; Rosenberger, H. G.; and Whiting, E. G.: Histoplasmin Sensitivity and Coccidioidal Infection. Am. J. Pub. Health, **39:** 722–736, 1949.
42. Sweigert, C. F.; Turner, J. W.; and Gillespie, J. B.: Clinical and Roentgenologic Aspects of Coccidioidomycosis. Am. J. Med. Sciences, **212:** 652–673, 1946.
43. Wernicke, Robert: Ueber einen Protozoenbefund bei Mycosis fungoides (?). Centralbl. f. Bakteriol., **12:** 859–861, 1892.

THE INTERNAL ARCHITECTURE OF THE FEMUR AND ITS CLINICAL SIGNIFICANCE

The Upper End *

BY WILLIAM J. TOBIN, M.D., WASHINGTON, D. C.

The purpose of this paper is an objective presentation of the internal architecture of the femur; it is not intended as a mathematical analysis. The femur was selected for study because of its size, its complexity of design, and the frequency with which the clinician is confronted with congenital, developmental, and acquired deformities of this bone. A thorough knowledge of its internal structure is essential to the surgeon who assumes the responsibility of treating such conditions. Because of the many aspects of the subject, this paper is limited to the internal architecture of the upper end of the femur. The variations from the normal, represented by coxa vara and coxa valga, will be considered. In a subsequent paper the architecture of the shaft and of the distal end will be discussed.

The clinical significance of the internal architecture of the femur is evident when one considers the great number of operative procedures performed on the upper end of the femur. It is not the intent of the author to suggest, even by implication, that some procedures or materials are to be preferred to others.

HISTORICAL BACKGROUND

From a chronological viewpoint, the earliest mention of the mechanics of bone is accredited by Koch to Galilei who, in 1638, referred to the importance of the form of bone. It was not until two hundred years later that the relation between the overhanging

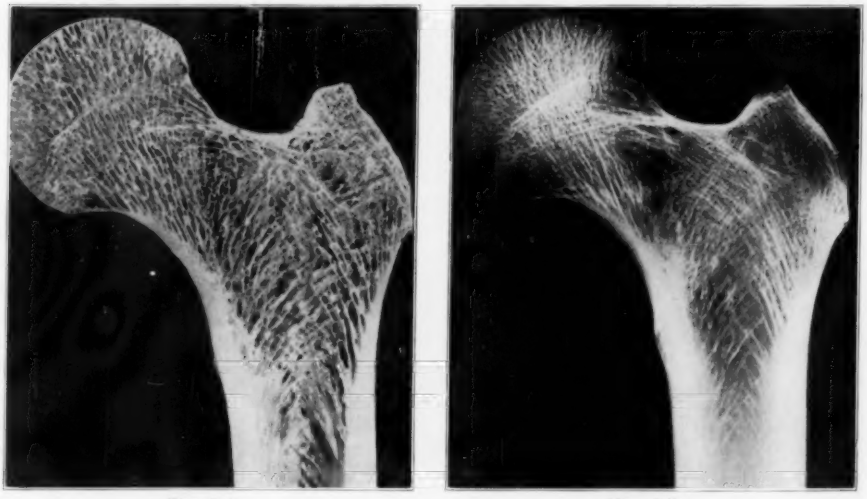

Fig. 1-A

Fig. 1-B

Section (Fig. 1-A) and roentgenogram (Fig. 1-B) of the upper end of the normal femur, showing distribution of the major trabecular systems. Note the area of lessened density in the specimen and in the roentgenogram. (Reproduced by permission from Instructional Course Lectures, The American Academy of Orthopaedic Surgeons, 1953. Vol. 10, p. 215, 1953.)

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 25, 1954.

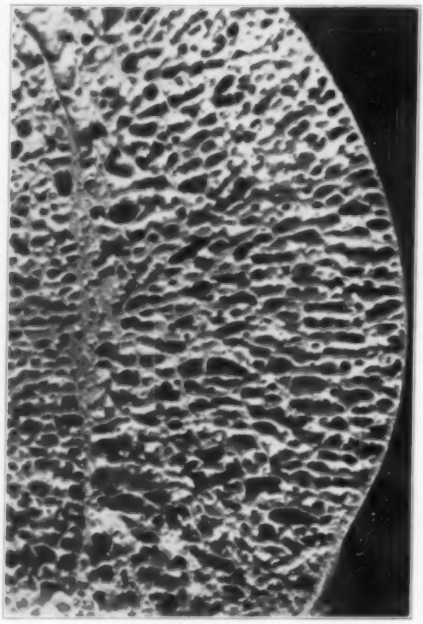

FIG. 2-A

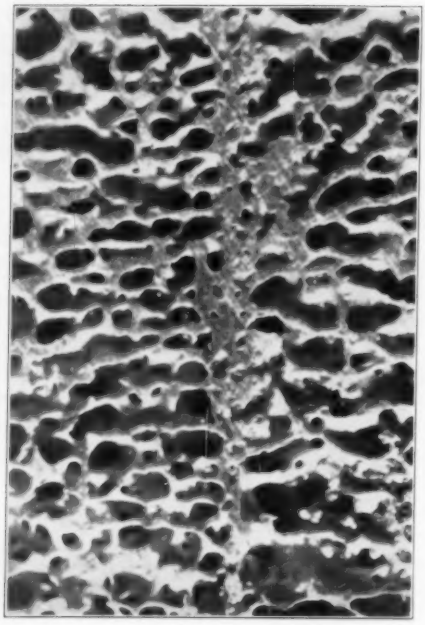

FIG. 2-B

Fig. 2-A: Section of a femoral head. Note the dense, closely woven trabeculations; note also the trabeculations intersecting the articular surface at right angles.

Fig. 2-B: Close-up photograph, showing relationship of compression trabeculations to the "epiphyseal scar".

Fig. 3. Section from a femoral shaft in the subtrochanteric area. Note the secondary compression and tension trabeculations arising from the inner aspect of the lateral and medial cortices.

FIG. 3

head and the distribution of the trabeculations in the upper end of the femur was appreciated. In 1838, Ward, in his *Human Osteology*, compared the neck of the femur to the bracket supporting a street lamp or a derrick. He compared the oblique-upright supporting structure to the strong trabeculations which continue upward from the medial inferior portion of the neck of the femur, extending into the head. The more horizontal part of the bracket was compared with the group of trabeculations hereafter referred to as the tension trabeculations, arising from the trochanteric region, arching superiorly and medially, and intersecting the compression trabeculations at right angles. These two major trabecular systems are connected by a third system between the trochanters which forms an area of lessened density, to which the appropriate term "trigonum internum femoris" or "Ward's triangle" has been given. The development of

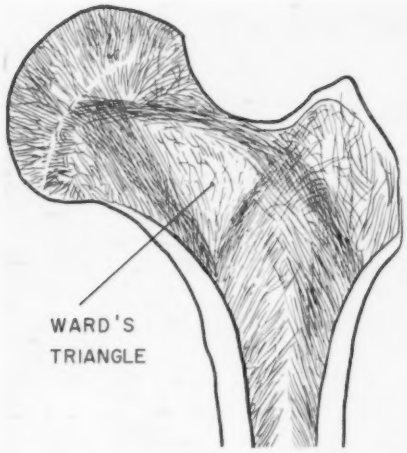

FIG. 4-A

Fig. 4-A: Diagram showing the triangular area of structurally weak trabeculations in the neck of the femur—Ward's triangle, or the trigonum internum femoris. (Reproduced by permission from Instructional Course Lectures, The American Academy of Orthopaedic Surgeons, 1953. Vol. 10, p. 215, 1953.)

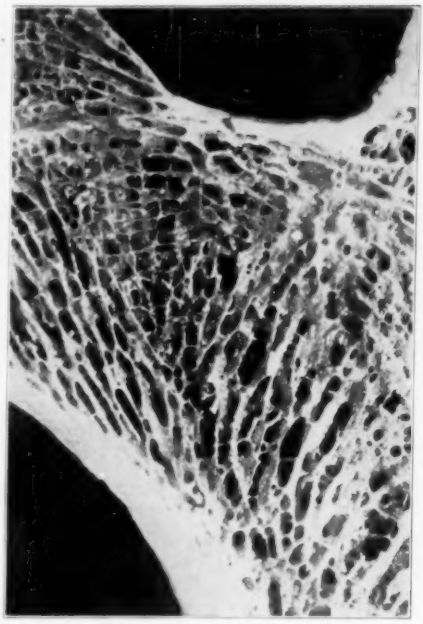

FIG. 4-B

Fig. 4-B: Close-up photograph of the trabecular pattern in the neck of the femur. The triangular area of loosely woven trabeculations (trigonum internum femoris) can be easily identified.

this structurally weak area and its clinical significance in fractures of the neck of the femur will be discussed later.

In 1858, Humphry [6], in a further description of the internal architecture of the upper

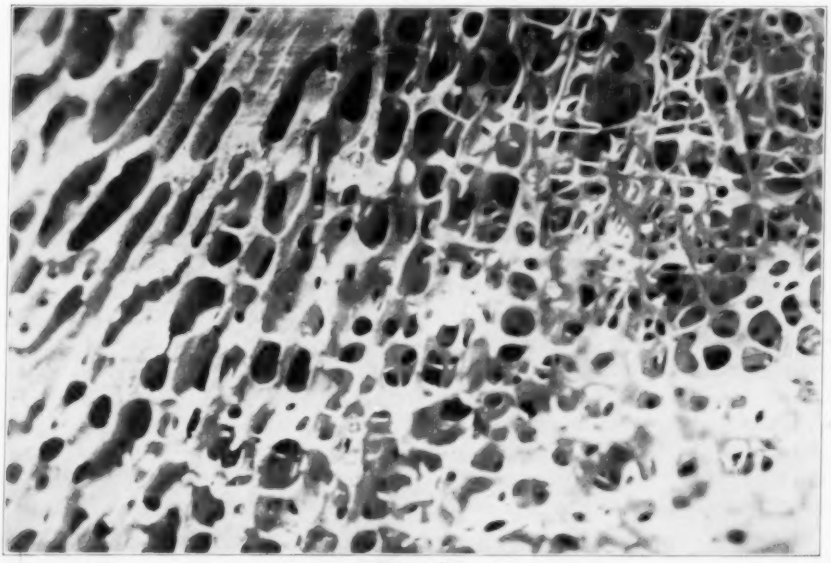

FIG. 4-C

A section from the neck of the femur. Note the dense compression trabeculations on the right and the thin honeycomb trabeculations in the area of Ward's triangle on the left.

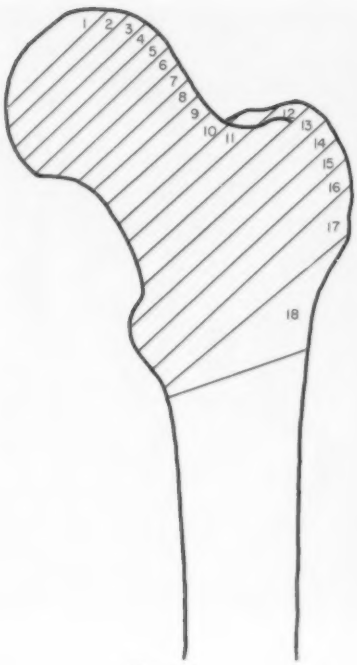

FIG. 5-A

FIG. 5-B

Fig. 5-A: Diagram showing the levels at which the sections shown in Figs. 5-C, 5-D, and 5-E were made.

Fig. 5-B: Roentgenogram of a normal femur selected for sectioning. Note the compression and tension trabeculations, the epiphyseal scar, and the triangular area of lessened density in the neck of the femur.

end of the femur, also observed that the two major trabecular systems intersected at right angles in the neck of the femur, and that the trabeculations extending to the articular surface were perpendicular to the articular surface of the head of the femur.

H. von Meyer, in 1866, at a meeting in Zürich, demonstrated the architecture of the upper end of the femur; and Culmann, an engineer and mathematician, compared the internal architecture of the upper end of the femur with the structure of the crane. Culmann stated that the design of the upper end of the femur was based upon the same basic mathematical principles as the structure of the crane. He also believed that static pressure bending the femur would cause stress on the concave side and tension on the convex side. He, too, pointed out that the major trabeculations intersected at a right angle in the crane, as well as in the upper end of the femur.

Despite the controversial aspects of the laws of bone architecture, credit must be given to Julius Wolff [21-26] for having first put forth in an organized manner the law of bone architecture which bears his name. According to Keith, Wolff's law is generally translated thus: "Every change in the form and the function of a bone or of their function alone, is followed by certain definite changes in their internal architecture, and equally definite secondary alterations in their external conformation, in accordance with mathematical laws". Wolff, in *Das Gesetz der Transformation der Knochen*, emphasized his observation that the major trabecular patterns intersected at right angles and termed this "orthogonality".

Roux agreed with Wolff that the internal architecture of the femur was the result of the forces acting externally upon it. One of the controversial questions arising from Wolff's law is whether or not tension causes bone formation or bone resorption. Wolff himself

believed that, wherever stresses of pressure and tension are caused in a bone, whether by pressing forces or by pulling forces, the formation of bone takes place. Wolff and Roux held that both tension and stress cause bone formation, and that these forces always intersect at a right angle.

It was felt by Keith that Wolff had little or no knowledge of the activity of the osteoblasts, the true bone-builders or architects of bone. Keith described the osteoblasts as the expert and unerring engineers of bone, and felt that it would be better to refer to the laws of osteoblasts rather than to Wolff's law. The important factor is that osteoblasts must be subjected to pressure and stress or tension in order to function, — that is, they must be stimulated to function. Keith felt that Wolff should be given credit for establishing the plasticity of bone, but that his law does not give credit where it is due, to the osteoblasts.

In 1902, Freiberg, in a discussion of Wolff's law, felt that it was difficult to evaluate Wolff's law because of the many factors acting

FIG. 5-C

FIG. 5-D

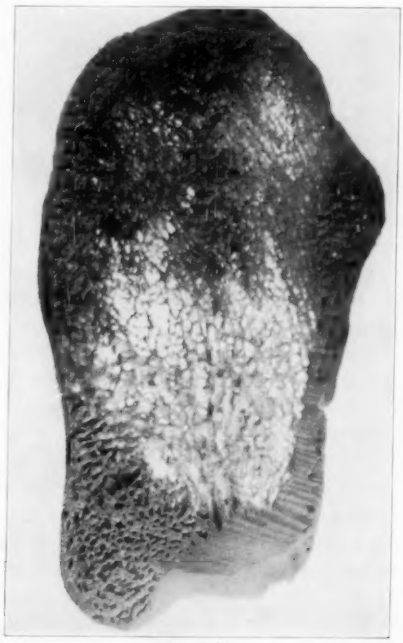

FIG. 5-E

Fig. 5-C: Section *12*, transilluminated. Note the thickened inferior medial portion of the neck, the site of the calcar femorale, and the loosely arranged trabeculations through the trigonum internum femoris.

Fig. 5-D: Section *14*, transilluminated at the intertrochanteric level. The upper trabeculations below the greater trochanter represent the tension group (lateral view).

Fig. 5-E: Section *16*, showing loosely arranged trabeculations in the trochanteric area (medial view).

FIG. 6-A

FIG. 6-B

Sections from the neck and the upper portion of the shaft of two femora, one from a child five years old and one from a child six and a half years old. Note the absence of a clear-cut triangular area of structurally weak trabeculations in the neck of the femur.

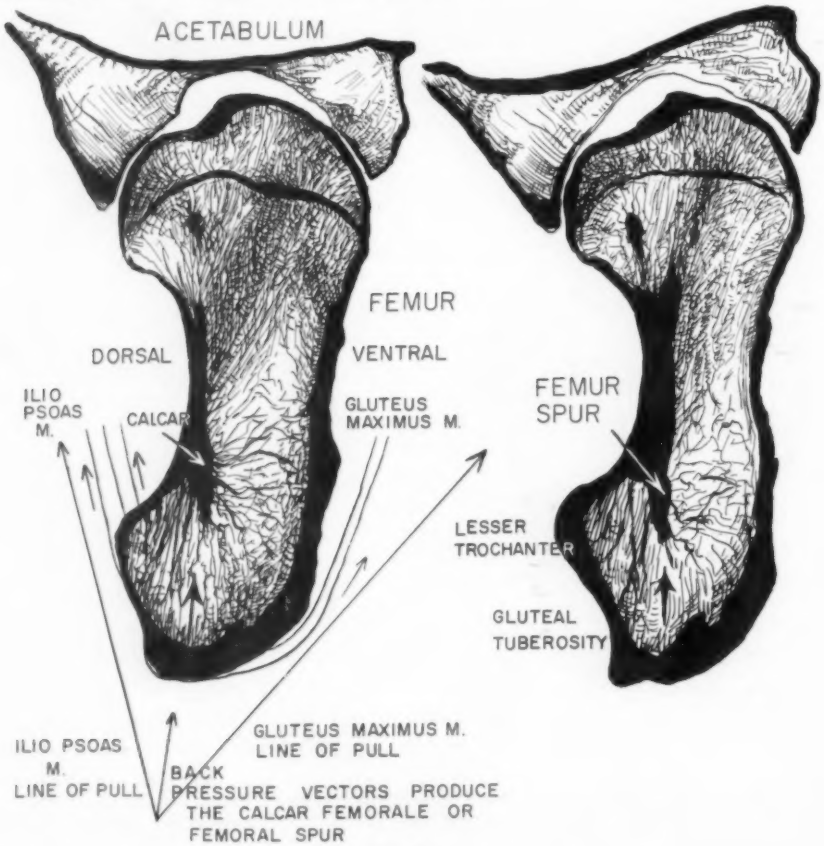

FIG. 7-A

(*See page 63*)

Fig. 7-A: Drawing made from roentgenograms of sagittal sections of the head and neck of the femur. Note the position of the calcar femorale, or femoral spur. (Redrawn from, and used by permission, Carey, E. J.: Studies in the Dynamics of Histogenesis. *Radiology*, **13**: 149, 1929.)

Fig. 7-B: Section of a femur, with the cancellous bone dissected away, showing the calcar femorale, which is a condensation of bone on the medial and inferior aspects of the neck just above the lesser trochanter.

FIG. 7-B

on the living femur which would not be evident in a removed femur. Taylor summarized the discussion by saying: "In conclusion, I consider that all of us must concur fully with Wolff that pressure does not produce atrophy in bone, as Lorenz has claimed, under pathologically increased or transposed burdening; and also we must admit that functional transformation of bone must and does occur to meet the altered static demands of pressure, tension, and shearing strain".

Taylor further stated that most orthopaedic surgeons lacked the qualifications in higher mathematics and engineering for the detailed mathematical calculations necessary to prove or disprove Wolff's law.

In 1920, Murk Jansen, in a monograph, *On Bone Formation*, took issue with many of the premises of Wolff's law. Jansen reviewed the hypothesis raised for the upper end of the femur by Culmann, applied to the other bones by von Meyer, established mathematically by Wolff, and confirmed anatomically by Roux, which had survived for over half a century as an accepted basis in the mechanics of bone, and rejected the "dualistic" theory of Culmann, von Meyer, and Wolff. Jansen felt that the major trabecular systems do not always cross at right angles, and therefore did not accept the theory of orthogonality. He also questioned whether bone formation was stimulated in the same manner by tension as by pressure, and whether bone formation was dependent upon mechanical stresses alone. Most of the previous authors had considered that the static pressure from body weight in the erect position was the predominant contributing factor in bone formation. Jansen felt that muscle pull or dynamic action played an equally important part in the formation of bone and had a very deciding influence on the structure of cancellous bone. He called attention to the diverging bone trabeculations which radiated from the intercondylar notch in the lower end of the femur, and suggested that these might be the result of some rotation factor. Bone trabeculations, according to Jansen, do not assume a direct straight mathematical course, but tend to undulate.

Kushner felt that Jansen's deductions were only partly true, to the extent that undue tension would result in atrophy. He contended that there is sufficient clinical evidence in bone grafts in the patella, as in the Albee method, and in spine fusions, where a factor of tension is certainly present, to show that moderate tension is a stimulus to bone formation.

Carey, in 1929, stated that the architecture of cancellous bone was the result of the pressure factors of muscle action rather than of the static pressure of body weight. He believed that the dense group of trabeculations which extend from the medial aspect of the upper portion of the femoral shaft were the result of the influence of the flexion-adduction muscles. The previously described tension trabeculations were interpreted as

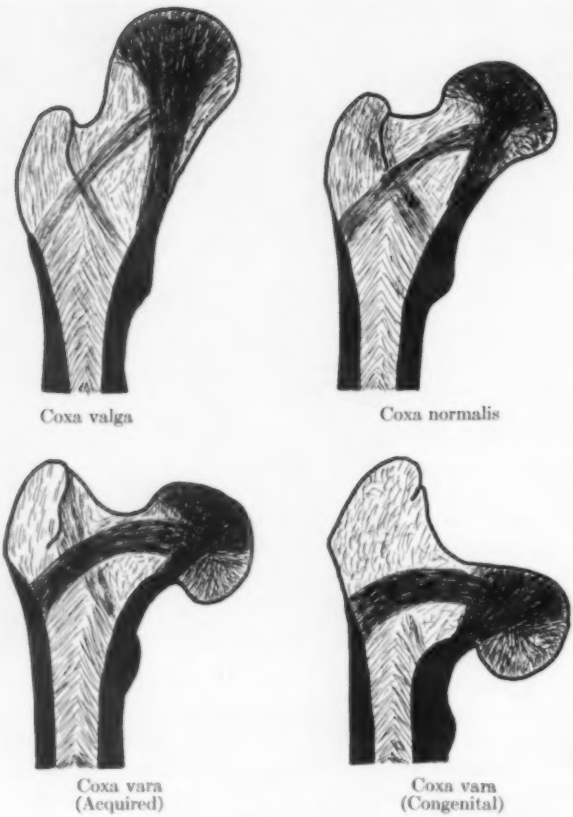

Fig. 8-A

Diagrammatic representation of alterations in the distribution of major trabecular patterns in coxa valga, coxa normalis, coxa vara (acquired), and coxa vara (congenital). Note the intensity of the compression forces in coxa valga and the tension forces in coxa vara.

being due to extension and abduction of the hip joint. Carey felt that the dynamic force of the muscles may exceed the static pressure of body weight. Jansen and Carey both believed that the major trabecular systems do not intersect at a right angle.

THE INNER ARCHITECTURE OF THE UPPER END OF THE NORMAL FEMUR

The upper end of the femur consists of the head, neck, and greater and lesser trochanters. From a morphological viewpoint, the head is spherical or globular in shape, forming more than a hemisphere. It is directed upward, inward, and backward. In the upright position the head and neck point downward, outward, and a little forward. The anterior inclination or anteversion varies considerably, the average being 25 degrees [19].

According to Steindler, a plane laid through the circumference of the acetabulum intersects the sagittal plane of the body at a "backward opening" angle of 40 degrees, and the transverse plane of the body at an "outward opening" angle of 60 degrees.

Humphry, in discussing the neck of the femur, mentioned that: (1) the angle varies in different subjects of the same age; (2) it is smaller in short than in long bones, and is usually small when the pelvis is wide, being smaller in men than in women; (3) the angle decreases during the period of growth, but once growth has been completed, there is no change, regardless of age; and (4) in a bed-ridden patient suffering from paralysis, once growth has been attained, the angle retains the form of early life, or may become wider. The anatomical axis corresponds to a line drawn down the middle of the shaft, whereas the true mechanical axis is a line drawn from the middle of the head to the intercondylar region of the distal end of the femur. The upper end of the femur is predominantly cancellous bone. It may be mentioned that cancellous bone, weight for weight, is as strong as cortical bone. The trabeculations are more closely arranged when greater weight is supported. This has been observed in the roentgenographic study of an elephant's femur.

There are two main trabecular patterns or systems in the upper end of the femur: first, the compression group, which arise from the medial portion of the shaft and extend upward into the head; second, a tensile group arising from the lateral portion of the shaft and curving upward, ending in the upper portion of the neck and inferior portion

of the head. These two systems intersect at right angles. There is a third group which connects the two principal groups (Figs. 1-A and 1-B).

At about the level of the lesser trochanter the medial trabeculations extend upward from the medial portion of the shaft. This group of trabeculations may be subdivided into a primary and a secondary group. The primary, or principal, group constitute the main compressive group of trabeculations. These extend upward in a slightly radial manner to the articular surface of the head of the femur. They constitute the thickest trabeculations in the upper end of the femur. In essence they may be considered an upward extension of the medial part of the shaft. These trabeculations intersect the articular surface of the head of the femur at right angles (Figs. 2-A and 2-B). The secondary compressive group curve away from the shaft at an angle of approximately 45 degrees, and are directed outward and upward to cross the trabeculae from the opposite direction. The trabeculations of this group are not as thick as those of the principal compressive group (Fig. 3).

FIG. 8-B

Longitudinal section showing a congenital coxa vara. Note the relation of the upper level of the greater trochanter to the head and the thickness of the inferior portion of the neck.

Koch stated that it was quite deceptive to interpret the right-angle intersections of curved lines. The correct method for meas-

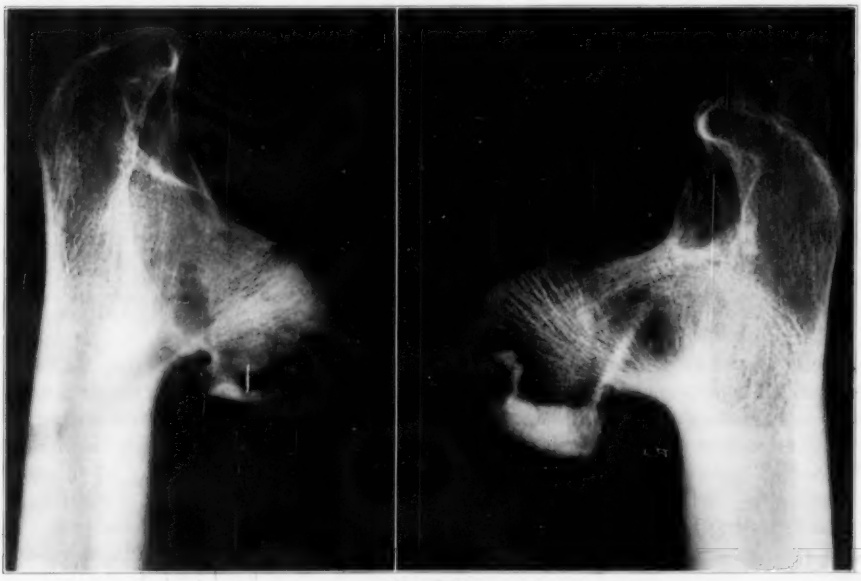

FIG. 8-C

Roentgenograms showing congenital coxa vara. Note the thickness of the inferior portion of the neck and the intensity of the tension lines on the right. The trigonum internum femoris is well delineated.

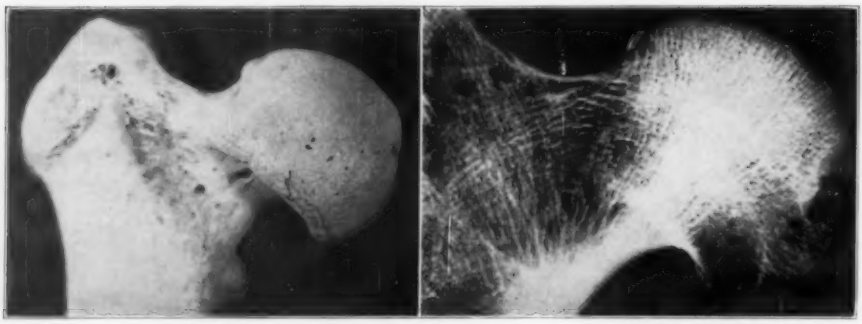

FIG. 8-D FIG. 8-E

Acquired coxa vara. Note "overhanging" of the head on the neck. In the roentgenogram (Fig. 8-E) note the alterations in the distribution of the trabecular patterns to meet the increased shearing forces and the altered static demands on the head and neck. (Reproduced by permission from Instructional Course Lectures, The American Academy of Orthopaedic Surgeons, 1953. Vol. 10, p. 217, 1953.)

FIG. 8-F

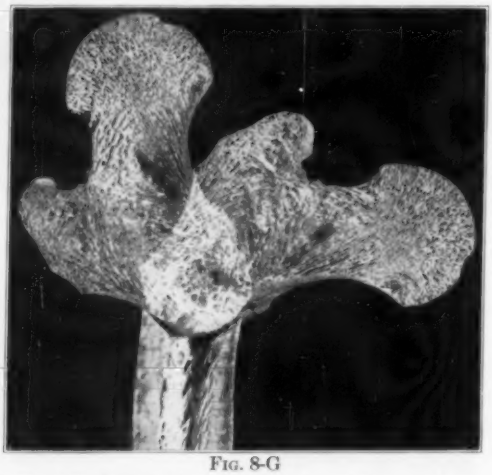

FIG. 8-G

Fig. 8-F: Acquired coxa vara from malunion of a fracture of the upper femoral shaft. Note the thickening of the inferior portion of the neck, intensity of the tension lines, and extension of the compression lines to the lateral cortex. (Reproduced by permission from Instructional Course Lectures, The American Academy of Orthopaedic Surgeons, 1953. Vol. 10, p. 219, 1953.)

Fig. 8-G: Double-exposure photograph to show the desired alteration of coxa valga from coxa vara brought about by subtrochanteric osteotomy.

urement of the angle between two curved lines is to draw through their intersection straight lines perpendicular to the radius of each curve; the angle between these two intersecting straight lines is the angle between the two curves at their intersection.

The compact bone in the lateral portion of the shaft becomes thinner as it reaches the level of the greater trochanter. The tension group of trabeculae may be subdivided, according to Koch, into (1) those arising from the upper part of the shaft and extending vertically upward, ending in the greater trochanter; (2) those arising lower in the shaft from an angle of approximately 30 to 45 degrees, crossing in almost parallel curved lines through the neck of the femur, and intersecting the principal compressive trabeculations at a right angle; and (3) those crossing the longitudinal axis of the femur and ending on the medial side of the neck and shaft.

FIG. 9

FIG. 10

Fig. 9: Acquired coxa valga from malunion of a fracture of the upper third of the femoral shaft. Note the increased density of the compression lines. (Reproduced by permission from Instructional Course Lectures, The American Academy of Orthopaedic Surgeons, 1953. Vol. 10, p. 219, 1953.)

Fig. 10: The upper end of the femur of a sloth, which lives "upside down". Minimal or no static forces are present, while the influence of muscle forces is evident. Note the nondescript trabecular pattern and extension of cancellous bone into the shaft.

There is a structurally weak triangular area in the neck of the femur which is comprised of rather loosely arranged thin trabeculations. This was described by Ward and is known as "Ward's triangle", or the "trigonum internum femoris" (Figs. 4-A, 4-B, and 4-C). This area is of importance, as it is through it that the majority of fractures of the femoral neck occur. It is logical to assume that in the elderly, as osteoporosis progresses, an area which is basically weak will become weaker (Figs. 5-A through 5-E).

Smith mentioned the significance of the trigonum internum femoris in fractures of the neck of the femur. This triangular area is not well defined in prenatal and postnatal periods and in childhood (Figs. 6-A and 6-B), but becomes apparent in early adolescence and is more distinct as bone maturity is reached. It is well delineated in the aged, particularly in the female with osteoporosis. In this sense it is developmental. In the ever increasing size and changing internal architecture of the developing femoral neck, the compression trabeculations are more clearly defined than the tensile trabeculations. This area probably represents a lack of stimulation to trabecular formation. Little demand is exerted on this area of the neck of the femur from either the static or the dynamic viewpoint.

The calcar femorale is a condensation of bone on the medial and inferior aspects of the neck just above the lesser trochanter. This was considered as the true neck of the femur and is best illustrated by sections through the lower surface of the neck. Lewis felt that it was the attenuation of this structure which played an important part in fractures of the neck of the femur in the aged.

FIG. 11-A

Close-up view, showing the relationship of the nail to the loosely woven trabeculations in the femoral neck. These trabeculations do not give adequate support to the nail.

FIG. 11-B

Fig. 11-B: The nail is shown in the low-placed valgus position resting on the calcar femorale. This affords the best mechanical fixation and places the nail in line with major compressive forces.

FIG. 12

Fig. 12: Showing the Frederick Thompson type of prosthesis. The head and part of the neck of the femur have been removed. The inferior portion of the prosthesis rests on the calcar femorale and the lateral aspect of the intramedullary portion rests against the medial aspect of the lateral cortex of the shaft.

While the proponents of the static theory attribute this structure to the result of compression forces, Carey and others concluded that it is a condensed group of trabeculations resulting from back-pressure vectors produced by the flexor and adductor muscles

of the hip (Fig. 7-A). The calcar femorale can be demonstrated by dissecting away the surrounding less dense trabeculations (Fig. 7-B).

COXA VARA

Mercer divides coxa vara into the congenital and the acquired type. He divided the acquired type into four groups, according to the anatomical site involved: (1) capital coxa vara, as in Perthes' disease and destructive arthritis; (2) epiphyseal coxa vara, idiopathic and traumatic; (3) cervical coxa vara; and (4) trochanteric coxa vara. In coxa vara there is a decrease in the angle between the neck and the shaft of the femur. The angle approaches a right angle or, in the case of congenital coxa vara, it may be acute (Fig. 8-A). There is also a backward twist of the head, with an outward rotation of the shaft. The internal architecture is altered in accordance with the angle formed by the shaft with the neck of the femur (Fig. 8-B). There is an increased static shearing force due to the decreased angle. In the roentgenograms there is a marked increase in the density and concentration of the compression trabeculations with thickening of the inferior portion of the neck and medial cortex of the shaft (Fig. 8-C). The tension or tensile group of trabeculations appear to be much stronger and more pronounced than in the normal, and the two major trabecular systems appear to intersect each other at right angles.

In acquired coxa vara there results a rearrangement of the trabecular patterns to fulfill the demands made by the altered relationship of the neck to the shaft (Figs. 8-D and 8-E). The coxa vara resulting from a malunion in a high femoral-shaft fracture (Fig. 8-F) illustrates clearly these architectural changes. The tension trabeculations are more pronounced than in the average femoral neck. This probably is the response to the increased shearing force incidental to the coxa vara. In the roentgenograms shown the compression trabeculations extend through the inferior cortex of the neck to the opposite femoral cortex at a lower level in order to give additional support.

It can be clearly seen that coxa vara, from a mechanical viewpoint, is an undesirable position. The change in position of the major trabecular systems attained by a subtrochanteric osteotomy is shown in Figure 8-G.

COXA VALGA

In coxa valga the angle formed by the neck and shaft of the femur is obtuse. Coxa valga may be acquired or congenital. In the acquired group the condition may result from fractures with malunion, or from paralysis, as in poliomyelitis, with involvement of the muscles about the hip.

A moderate degree of coxa valga is illustrated in Figure 9. In this condition the compression forces are intensified, while the tension trabeculations are not as prominent as in coxa vara.

As mentioned previously, there has been considerable controversy on the effect of static and dynamic forces on the formation of bone trabeculations. If the proponents of the influence of muscle in the formation of trabecular patterns are correct in their premise, one would expect definite trabecular patterns to be present under those conditions which indicate that muscle function is present, but static weight-bearing is minimized. If the upper end of the femur of the sloth, which lives "upside down" and lacks the stimulation of weight-bearing, is taken as an example, some response to back-pressure muscle vectors should be manifested in the internal architecture (Fig. 10).

In the roentgenograms of the femur of a sloth there are no well defined compression or tension lines. This might be interpreted as substantiating the premise of the proponents of the static theory as the principal causative factor in the development of the major compressive and tension trabecular groups. It is probable that both static and dynamic factors and the muscle pull influence the distribution of trabecular patterns.

CLINICAL APPLICATIONS

The internal fixation of fractures of the neck of the femur is used to demonstrate the necessity of embodying basic engineering principles and to correlate the fixation material with the internal architecture of the upper part of the femur. For illustrative purposes the triflanged nail was used in sections of the femur.

The primary function of any type of fixation is to immobilize the fragments and to transmit the weight or other forces from the head to the shaft of the femur. The proper insertion of the nail is of paramount importance. It is obvious that insertion of the nail in a varus position is mechanically unsound.

From the preceding discussion on the character of the internal architecture of the head and neck of the femur, it can be seen that even a nail placed in the central part of the neck and head is not in the best position (Fig. 11-A). Because of the cancellous structure, there is little opportunity for good fixation by the nail. The only site of supporting cortical bone is the entrance point in the outer cortex of the femur, the stability of which is often lessened as a result of the insertion of the nail. The area of lessened density in the neck (trigonum internum femoris) offers little support to the nail. The centrally placed nail is along the neutral or anatomical axis, which is mechanically unsound for supporting a stress load.

From the points of view of bone architecture and engineering the position of choice is a low-placed nail in valgus position, actually resting on the calcar femorale, which offers the best support in the neck of the femur (Fig. 11-B).

Haboush advocated the use of a nail plate in transcervical fractures of the femur.

Dickson, in discussing the "unsolved" fracture, emphasized the mechanical advantage of the nail being placed low, resting almost on the calcar femorale, and being centrally placed in the head, to afford maximum fixation to the fragments.

The same general principles apply in the use of prostheses. In the Judet type of prosthesis, if the stem or nail portion is inserted in a valgus position, so that it rests not only on the exposed portion of the neck but also on the dense portion of the medial cortex, adequate fixation is possible.

The intramedullary type of prosthesis, such as the Frederick Thompson type, has the added advantage that the inferior portion of the prosthesis rests directly on the calcar femorale, and the lateral aspect of the intramedullary portion of the prosthesis rests against the medial aspect of the lateral cortex of the femur. As has been said, however, it is not the intent of the author to advocate any particular type of fixation or prosthetic appliance (Fig. 12).

NOTE: The author is indebted to the Divisions of Physical Anthropology and Mammals, United States National Museum, Smithsonian Institution, for the material studied; and to the Georgetown University Medical Center and the Armed Forces Institute of Pathology for their cooperation in the preparation of this paper. This investigation was supported by the James Picker Foundation on recommendation of the Committee on Radiology, National Research Council.

REFERENCES

1. CAREY, E. J.: Studies in the Dynamics of Histogenesis. Radiology, **13:** 127–168, 1929.
2. CULMANN, C.: Die graphische Statik. Zürich, 1866.
3. DICKSON, J. A.: The "Unsolved" Fracture. A Protest Against Defeatism. J. Bone and Joint Surg., **35-A:** 805–822, Oct. 1953.
4. FREIBERG, A. H.: Wolff's Law and the Pathogenesis of Deformity. Am. J. Med. Sciences, **124:** 956–972, 1902.
5. HABOUSH, E. J.: Biomechanics of Femoral Nail and Nailplate Insertions in Fractures of the Neck of the Femur. Bull. Hosp. Joint Dis., **14:** 125–137, 1953.
6. HUMPHRY, G. M.: A Treatise on the Human Skeleton (Including the Joints). Cambridge, Macmillan and Co., 1858.
7. HUMPHRY, G. M.: On the Angle of the Neck of the Thigh Bone with the Shaft at various ages and under various circumstances. (Abstract.) Lancet, **2:** 971, 1888.

8. Jansen, Murk: On Bone Formation. Its Relation to Tension and Pressure. London, Manchester University Press, 1920.
9. Keith, Arthur: Menders of the Maimed, pp. 277–289. London, Oxford University Press, 1919.
10. Koch, J. C.: The Laws of Bone Architecture. Am. J. Anat., **21:** 177–298, 1917.
11. Kushner, Alexander: Evaluation of Wolff's Law on Bone Formation. J. Bone and Joint Surg., **22:** 589–596, July 1940.
12. Lewis, Dean: Clinical and Topographic Anatomy. *In* Morris' Human Anatomy, edited by C. M. Jackson. Ed. 7, p. 1433. Philadelphia, P. Blakiston's Son and Co., 1923.
13. Mercer, Walter: Orthopaedic Surgery. Ed. 2, p. 440. Baltimore, Williams Wood and Co., 1937.
14. von Meyer, H.: Die Architectur der Spongiosa. Reichert und Dubois-Reymond's Archiv, pp. 615–628, 1867.
15. Roux, W.: Das Gesetz der Transformation der Knochen. Berliner Klin. Wochenschr., **30:** 509–511, 533–535, 557–558, 1893.
16. Smith, L. D.: Hip Fractures. The Role of Muscle Contraction or Intrinsic Forces in the Causation of Fractures of the Femoral Neck. J. Bone and Joint Surg., **35-A:** 367–383, Apr. 1953.
17. Steindler, Arthur: The Mechanics of Normal and Pathological Locomotion in Man. Springfield, Ill., Charles C. Thomas, 1935.
18. Taylor, R. T.: A Discussion of Wolff's Law. Am. J. Med. Sciences, **124:** 972–979, 1902.
19. Tobin, W. J., and Stewart, T. D.: Gross Osteopathology. The Upper End of the Femur. *In* Instructional Course Lectures, The American Academy of Orthopaedic Surgeons, 1953. Vol. 10, pp. 213–223. Ann Arbor, J. W. Edwards, 1953.
20. Ward, F. O.: Outlines of Human Osteology, p. 370. London, Henry Renshaw, 1838.
21. Wolff, Julius: Ueber die Bedeutung der Architectur der spongiösen Substanz. Centralbl. f. die Med. Wissensch., **54:** 849–851, 1869.
22. Wolff, Julius: Ueber die innere Architectur der Knochen und ihre Bedeutung für die Frage von Knochenwachstum. Virchows Arch., **50:** 389–450, 1870.
23. Wolff, Julius: Das Gesetz der Transformation der inneren Architectur der Knochen bei pathologischen Veränderungen der äusseren Knochenform. Sitzungsber. d. Kön. Preuss. Akad. d. Wissensch., pp. 475–496, 1884.
24. Wolff, Julius: Die Lehre von der funktionellen Knochengestalt. Arch. f. Path. Anat. u. Physiol., **155:** 256–315, 1889.
25. Wolff, Julius: Ueber die Theorie des Knochenschwundes durch vermehrten Druck und der Knochenanbildung durch Druckentlastung. Arch. f. Klin. Chir., **42:** 302–324, 1891.
26. Wolff, Julius: Das Gesetz der Transformation der Knochen. Berlin, Hirschwald, 1892.

DISCUSSION

Dr. Edward J. Haboush, New York, N. Y.: Dr. Tobin's paper on the internal architecture of the upper end of the femur presents a subject that my collaborator, Prof. Charles Wang, engineer and mathematician, and I have been keenly interested in since 1947. From the results of our research, it appears that the combined-stress theory best explains biomechanically the internal architecture of the femur. This theory not only conforms with the observations of Ward, Humphry, Meyer, Culmann, Roux, and Wolff, but also offers a sound explanation for those objections raised by Jansen, Carey, and others. In addition it also explains the abnormal variations of the upper end of the femur, such as coxa vara, coxa valga, and others so well shown in Dr. Tobin's beautiful illustrations.

An analysis of the internal architecture of the femur clearly indicates that the bony trabeculations are formed in the direction of the principal stresses of the combined-stress theory. The principal stresses are those having the maximum value either in tension or compression. Their direction is dictated by the manner in which the upper end of the femur is loaded. The upper end of the femur is comparable to a cantilever beam. The forces acting upon it are basically bending, shearing, tensile, and compressive. The combined principal stresses created by these forces are predetermined by the location of the neutral axis. All principal stresses above the neutral axis are tensile, those below are compressive. In a normal femur, when the neutral axis coincides with its central axis, the general direction of the principal stresses in tension is perpendicular to the direction of the principal stresses in compression. If there is an appreciable divergence between the neutral and the central axis, the directions of the principal stresses are not perpendicular to each other, and the bony tensile and compressive trabeculations will not be orthogonal. Therefore, if we modify Wolff's law by saying that "the bony trabeculations run in the same direction as the principal stresses", there can be no valid objections to it.

To discuss further the variations from the normal in coxa vara, either congenital or acquired, the neutral axis is shifted downward. This, together with a change in the axial components of the applied force, causes a greater increment of the principal stress in tension, thereby producing more tensile bony trabeculations. In coxa valga, the neutral axis shifts upward, and the change in the axial component of the applied force causes a greater increment of the principal stress in compression, thereby producing more compressive bony trabeculations. Dr. Tobin's illustrations substantiate these facts.

It is of particular interest to examine Figure 10 of Dr. Tobin's presentation. In the sloth the femoral neck is almost non-existent and in this case the applied force is a pure shear. The directions of the principal stresses of a body subjected to pure shear are at an angle of 45 degrees to the direction of the applied force. Dr. Tobin has stated that there are no compression or tension lines or trabeculations in the femur of the sloth, since it lives upside down. Upon careful examination of Figure 10, however, a condensation of the bony trabeculations in the direction of the principal stresses is clearly demonstrated and they are, in tension and in compression, at an angle of 45 degrees to the direction of the applied force. I should like to add also from our observations that bone formation does not occur in the direction of shear stress.

The combined-stress theory explains also the existence of Ward's triangle. Dr. Tobin mentioned that Ward compared the upper end of the femur to a street-light bracket. It is to be noted that in a simple cantilever beam the principal stresses of tension and compression are symmetrical. This is suitable for material with equal tensile and compressive strength. In the street-lamp bracket, triangular in shape, the central axis is inclinated upward for two basic reasons: first, to have the compression bar take the greater share of the load, since most materials have greater compressive strength; second, to reduce the pulling effect on the nail or screw fastening the tension bar to the lamp post. Comparison between the lamp bracket and the upper end of the femur clearly indicates that bone has greater strength in compression also.

It is of extreme interest also to note the comparison between Ward's triangle and a structural design of the lamp-post bracket. The structural design of the bracket is based on the principle of eliminating the central portion of a triangular plate, which does so little to support the load. This explains the existence of Ward's triangle, since that portion of the neck of the femur also supports so little of the load.

From what has been said it is a foregone conclusion that bone formation occurs along the directions of the principal stresses of the combined-stress theory. The principal stresses are dictated by the external configuration of the femur and the external forces acting upon it. Therefore, the statements of the earlier workers are basically correct, although they fail to offer a rigorous and complete explanation of bone formation.

Dr. Tobin's suggestions pertaining to clinical applications are in accordance with biomechanics and are a definite improvement over the present methods of treatment mentioned.

In my opinion, further research should be done biomechanically along these lines: First, a more comprehensive study should be made of the physical properties of bone, since our present knowledge is inadequate for modern analysis; and second, further study is necessary in contact stress, repeated stress, stress concentration, and combined bending, torsion, and buckling.

This knowledge would be extremely important for the following reasons: (1) to obtain a true evaluation of our present reconstructive surgical procedures; (2) possibly to alter surgically the bony configuration to stimulate bone formation which will correct bone abnormalities; (3) to obtain a further understanding of bony union and the treatment of non-union; and (4) to evaluate and more properly design internal-fixation and prosthetic appliances.

DR. CHARLES W. GOFF, HARTFORD, CONNECTICUT: This is a most interesting paper. A study of this nature might be extended indefinitely by perusal of the extensive literature, including the "stresscoat" technique of Evans and the plastic models of Haboush. Anatomists have pursued similar studies following the work of Wolff and Roux, both of whom were interested in comparative measurements of the intrinsic and extrinsic dimensions and designs of the femur, the largest weight-bearing bone of man. Significant values, in this regard, may be noted in other animal forms, notably the Primates, so intimately tied to man's past and particularly to his postural evolution.

There is an especially important bone-muscle relationship in terms of postural evolution, imposed upon the femur by our present-day cultural requirements with their trauma and diseases. Little is known of similar effects on the skeletal system of other Primates. They have no culture as it is known to man, and they have only recently been allowed to live as long as thirty-five years, the oldest age recorded in a captive chimpanzee. In their wild state these animals lose their lives much earlier through hunting and disease. These animal forms, as well as the American bear, are now being studied, to determine comparative stresses and strains in a new manner which is to be reported soon.

Spray and Widdowson, of Cambridge University, have shown recently that man has a greater sodium, calcium, and phosphorus body content than other Primates, largely because of his greater bone concentration. His muscles, however, as indicated by their study of the protein and potassium values, are not particularly unique. Thus there is more bone and less muscle in man than in other animal forms. Both of these characteristics are related to the demands of man's upright posture and the resultant requirement for greater stability. This also suggests that man has lost much of his muscle substance as his specialized body developed. Hence, the stresses and strains which produce the bone trabeculae of the upper end of the femur, while similar in man to those of other Primates, are nevertheless diminished. The over-all bony attachments are also less prominent and less rugged. These correlations between bone architecture in man and his evolution and the demands of his culture are suggested in Dr. Tobin's paper.

(*Continued on page 77*)

SPINAL OSTEOTOMY FOLLOWING FUSION FOR PARALYTIC SCOLIOSIS

BY DR. W. C. MEISS, THE HAGUE, NETHERLANDS

Operations on vertebrae to correct deformities of the vertebral column have been performed successfully for more than two decades. In 1932, Compere performed excision of hemivertebrae for congenital scoliosis; von Lackum and Smith, and later Wiles, also treated this anomaly by operations on the vertebral bodies. The method was never generally accepted, however, as the results were not always favorable. Bertrand, after two successful operations followed by two with fatal results, abandoned resection of a vertebral body in favor of osteotomy on the concave side.

In some cases, surgery of the vertebral column constitutes the last possibility of correcting deformities. The author's personal experience with vertebral osteotomy in the treatment of ankylosing spondylarthritis, as first reported by Smith-Petersen and later by la Chapelle, induced him to resort to lateral wedge osteotomy on the convex side in a female patient who had been almost completely disabled by severe lumbar scoliosis.

FIG. 1-A

FIG. 1-B

Figs. 1-A and 1-B: Photographs of the patient taken on July 6, 1951, ten years after spondylodesis.

Fig. 1-C: Diagram showing the bone graft which had been inserted at the first operation, in 1941.

FIG. 1-C

CASE REPORT

The patient was a girl who had had infantile paralysis at the age of three and who showed marked scoliosis when first seen by the author. In June 1941 spondylodesis was performed, with use of a tibial graft placed over the left aspect of the processus spinosus, following correction in a plaster-of-Paris corset according to the method of Risser. The initial result was satisfactory. The patient could not be followed during the War, however, and was not seen again until five years later. At that time, the condition was extremely unsatisfactory. Severe scoliosis had developed, as the graft had failed to grow with the adjacent bone. Correction in a plaster-of-Paris corset did not give sufficient improvement. Operation was suggested but was refused by the parents, and the girl was given a leather corset. In 1951, when the patient was eighteen years old, she showed marked lumbar scoliosis and, even with the aid of two canes, was unable to walk longer than five minutes, after which dyspnoea occurred. The diaphragm was elevated as a result of the kyphoscoliosis, and only inconsiderable thoracic respiration was possible. After a complete internal examination, which failed to reveal any anomalies, the parents gave permission to operate.

Operation was performed on July 12, 1951, under pentothal nitrous oxide anaesthesia. An incision fifteen centimeters long was made over the mid-portion of the vertebral column. The spinous processes were seen to

FIG. 1-D

FIG. 1-E

FIG. 2

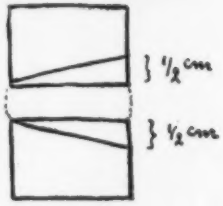

FIG. 3-A

Figs. 1-D and 1-E: Roentgenograms made July 6, 1951, showing the vertebral column ten years after spondylodesis. There was a severe kyphoscoliosis, with the highest point of the arch at the third lumbar vertebra, and extensive vertebral-body deformation from the twelfth thoracic vertebra to the first sacral segment.

Fig. 2: Roentgenogram made July 19, 1951, one week after the second operation, showing the defect at the posterior part of the vertebral column.

Fig. 3-A: Diagram showing the wedge removed from the lower part of the second and the upper part of the third lumbar vertebra.

FIG. 3-B

Fig. 3-B: Roentgenogram made November 27, 1951, three months after vertebral-body osteotomy. The kyphoscoliosis has been almost completely corrected. The bone chips used to fill the defect are visible.

Figs. 4-A and 4-B: Roentgenograms made May 30, 1954. The defect has been obliterated and the vertebral bodies are fused. The correction of the kyphoscoliosis has not changed.

FIG. 4-A

FIG. 4-B

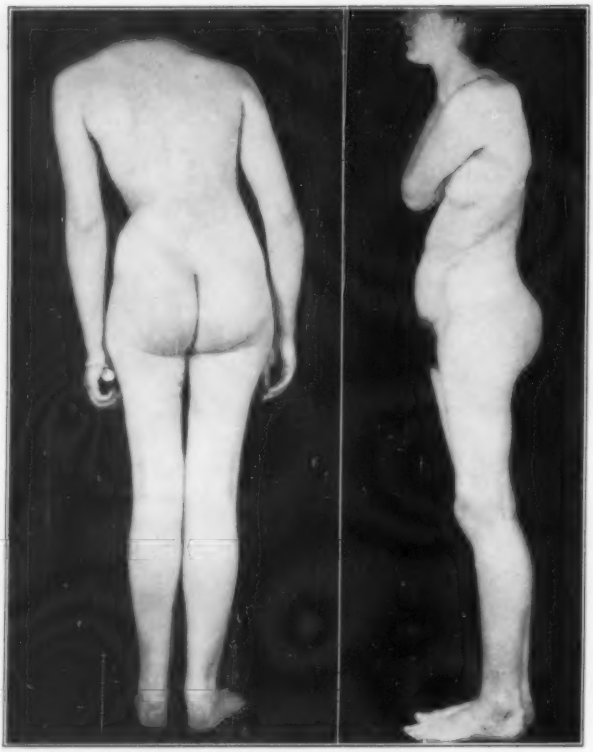

FIG. 4-C FIG. 4-D

Photographs taken on May 30, 1954.

the left of the median line and the transverse processes to the right. There was a large mass of bone which adhered to the spinous processes, the laminae, and the transverse processes. This mass had a thickness of three by four centimeters. It was impossible to chisel through this bone mass. A wedge, the base of which was two centimeters, was carefully started with a motor saw on the convex side and was then completed with an osteotome, the bone being gradually removed as far as the dura. (The operation was very much facilitated by the circumstance that the dura was not adherent to the bone.)

The right transverse process and the superior and inferior articular processes were removed. The resulting arterial hemorrhage was satisfactorily controlled by means of a hemostatic. The spinous process was also removed. Although the points of support on the posterior and right aspects had been removed, correction of the deformity was not yet possible. The left transverse process was then removed, together with the left inferior and superior articular processes, so that the vertebral column was supported only by the vertebral bodies; the dura was seen over a length of two centimeters.

This stage of the operation called for meticulous care in the use of the osteotome to safeguard the posterior nerve roots and the adjacent dura. The dura was protected by interposing an instrument between it and the mass of bone as soon as a small part of the dura had been exposed. Almost complete correction of the deformity was then accomplished as far as possible by gentle pressure and was maintained by placing the patient in plaster shells made at the time. There still existed, however, sufficient resistance to preclude complete straightening of the vertebral column. After four weeks the shells were omitted and the patient was recumbent on a firm mattress.

Both the patient and her family were content, but it was believed that this result could be improved and it was decided to perform a wedge osteotomy of the vertebral body.

On August 23, 1951, under pentothal nitrous oxide anaesthesia, an incision twelve centimeters long was made, parallel to the first incision and four centimeters to the right of it. After exposure of the bodies of the second and third lumbar vertebrae, which had come close to the body surface as a result of the extreme rotation of the vertebral column, the disc between the second and third lumbar vertebrae was excochleated. The resulting correction was still insufficient and it was necessary to remove with the osteotome a wedge from the lower part of the second and the upper part of the third lumbar vertebra (Fig. 3-A).

This was an extremely tense moment, for the vertebral column rested entirely on the two vertebral bodies which were being osteotomized. Besides the risk of causing spondylolisthesis there was the risk that the osteotome would slip and penetrate the dura. After each section of bone had been removed, the correction and the closing of the wedge were tested. Finally, correction seemed to have been achieved without separation of the vertebral bodies. Chips of preserved calves' bone were placed in the semicircular defect created at the second operation. The patient showed no postoperative shock and was given no transfusion. During the first operation 400 cubic centimeters of blood had been administered; at that time there had been no shock.

The postoperative course was uneventful. On September 14, 1951, the patient was given a plaster-of-Paris corset, in which she went home ambulatory three weeks later. She continued to wear the corset for six months; after that she was able to walk without dyspnoea.

The patient was seen again on September 2, 1953, and on May 6, 1954, two years and eight months after her last operation. She had learned to swim and was earning her living as a needlewoman; she walked with a cane (Figs. 4-A through 4-D).

Although the author does not consider the end result to be entirely satisfactory—the patient's back is not completely straight—he feels that this operation is indicated in the rare case in which the patient is severely disabled as a result of scoliosis. Some of the dangers which must be avoided are: (1) injuries to the posterior nerve roots; (2) injuries to the cord; (3) artificial spondylolisthesis during or after the operation and resulting in the two injuries described. Obviously, because of the great hazards involved, the operator should have a detailed knowledge of the regional anatomy, as well as extensive experience in operations on the vertebral column.

REFERENCES

BERTRAND, P.: Notions nouvelles dans le traitement chirurgical des scolioses graves. Rev. Chir. Orthop., **38**: 33–41, 1953.

LA CHAPELLE, E. H.: Osteotomy of the Lumbar Spine for Correction of Kyphosis in a Case of Ankylosing Spondylarthritis. J. Bone and Joint Surg., **28**: 851–858, Oct. 1946.

COMPERE, E. L.: Excision of Hemivertebrae for Correction of Congenital Scoliosis. Report of Two Cases. J. Bone and Joint Surg., **14**: 555–562, July 1932.

SMITH-PETERSEN, M. N.; LARSON, C. B.; and AUFRANC, O. E.: Osteotomy of the Spine for Correction of Flexion Deformity in Rheumatoid Arthritis. J. Bone and Joint Surg., **27**: 1–11, Jan. 1945.

VON LACKUM, H. LER., and SMITH, A. DEF.: Removal of Vertebral Bodies in the Treatment of Scoliosis. Surg., Gynec., and Obstet., **57**: 250–256, 1933.

WILES, PHILIP: Resection of Dorsal Vertebrae in Congenital Scoliosis. J. Bone and Joint Surg., **33-A**: 151–154, Jan. 1951.

DISCUSSION

THE INTERNAL ARCHITECTURE OF THE FEMUR AND ITS CLINICAL SIGNIFICANCE

(*Continued from page 72*)

In order to portray these factors more vividly, I revived a technique of Flourens, quoted by Roux and further developed by Benninghof and Tappen. This consists in decalcifying in a weak nitric-acid bath the upper third of dried femora of several species. After the outer cortical surface has been slightly softened through this acid action, a steel needle is used to tease apart the Haversian systems, which are then outlined with India ink floated into the linear depressions thus formed. In this manner markings were made from the zenith of the femoral head, distally to the intertrochanteric zone, and sweeping across this, down toward the shaft. These lines indicate stress columns, or trabeculations. These had been studied before the discovery of the roentgen ray. Some differences are immediately apparent between the higher Primates and man, as these preparations indicate.

The most interesting element is a dense zone which exists at the zenith of each human femoral head. This was clearly outlined by the ink markings. This dense plate is the point of contact of the femoral head with the acetabulum during the act of weight-bearing. It is also the zone which is the last to degenerate in the normal course of osteo-arthritis of the hip, and is the first zone to degenerate if there is a focal avascular necrosis of the subchondral bone. This interesting finding may be related to a new concept of causes and correlations of osteo-arthritis and avascular necrosis. It could be developed further if time permitted.

Lastly, may I call your attention to the early man fossil forms which have been found in South Africa. These all show femora which indicate postures relatively no different from those of modern man. They do show a small ape-like brain case. The Neanderthal man has usually been shown as having a marked bent-knee and flexed-hip stance. This is probably less so, according to recent studies. His culture was, of course, exceedingly primitive and his requirements were much more athletic. This accounts for his ruggedness and may be related to the findings of Spray and Widdowson.

May I encourage Dr. Tobin to continue to bring to the attention of other orthopaedists his revival of interest in the works of Wolff and Roux. A combination of methods, using the stresscoat technique of Evans

(*Continued on page 88*)

THE PRIMARY REPAIR OF TRAUMATIC DIGITAL SKELETAL LOSSES BY PHALANGEAL RECESSION

BY CARL E. NEMETHI, M.D., LOS ANGELES, CALIFORNIA

Phalangeal-recession surgery is indicated in those patients demonstrating large soft-tissue wound gaps when an entire phalanx or joint, or both, have been lost and the distal segment of the finger can be salvaged. In order to span the wound gap and to effect a successful repair, there must remain a viable soft-tissue bridge containing a functioning artery and nerve (or a reparable nerve), and the tissues distal to the wound must be viable. If the structures have been hopelessly crushed or otherwise devitalized so that necrosis is imminent, surgery will result in failure. There should also be sufficient bone structure to ensure a greater finger length than would result from amputation. Preservation of the distal phalanx with its highly specialized sensation, especially that of stereognosis, its nail, and general cosmetic value is our aim, together with retaining as much as possible of the over-all length of the digit.

It is not within the scope of this paper to embody the treatment of shock, the preparation and anaesthesia of the patient, or the meticulous débridement of the tissues. Careful observance and practice of the pertinent medical and surgical principles are "musts" upon which depend the success of the surgery.

Patients eligible for phalangeal recession should be operated upon within six hours of the time of injury. The longer the time elapsed, the more questionable is the chance of a good result. Only when shock has been controlled and pain has been alleviated, can careful clinical examination be made. The condition of the tissues can then be observed and the advisability of phalangeal recession can be determined. A complete roentgenographic study should be made. Adequate portable films can be made without removing the patient from the operating table. Roentgenograms should demonstrate not only the injured fingers but also the entire hand and wrist. Anteroposterior and lateral views are usually adequate; occasionally, oblique views are needed. Roentgenograms not only show the amount of bone remaining, but also furnish a permanent record of the injury.

Extension of the wound is necessary for adequate exposure and repair. Incisions follow the basic principles of plastic hand surgery; thus painful scars are avoided. Wounds are converted so that the resulting scars will not limit function. The large vessels are ligated with No. 000 plain catgut. The damaged bone surfaces are debrided with caution, so that all possible length may be retained, and the ends are impacted. Classical bone surgery cannot be used, lest too much length be sacrificed. After the skeletal gap has been closed, one Kirschner wire, drilled longitudinally through the cancellous center of the distal fragment and into the proximal segment, is usually sufficient for fixation. The finger must then be fixed in a normal functioning position and the excess wire must be cut off. Occasionally, the loss of bone is such that intramedullary fixation is not practical. It then becomes necessary to provide fixation by burying stainless-steel wires to approximate joint capsule or other soft tissues, or by pinning with Kirschner wires in some way other than intramedullarly.

The severed ends of the digital nerves are dissected free, resected into normal tissue, and an end-to-end anastomosis is effected with interrupted black silk sutures (No. 000000 or finer), uniting the sheath in the classical manner. Without adequate nerve supply, reconstructive work is to no avail, since the finger would only atrophy and become an insensitive claw. Severed tendons are debrided and are permitted to retract, no attempt being made to repair. Intact tendons are left undisturbed. It is found that the slack of the flexors is absorbed by muscular compensation during the convalescent period. Closure of the soft tissues is done with No. 36 interrupted stainless-steel wire sutures. The shortening

process and closure of the wound result in a bulging of the soft-tissue bridge. This redundant tissue is shaped in a smooth arc to prevent vessel-kinking and thrombosis. Denuded

FIG. 1-A

FIG. 1-B

Fig. 1-A: Roentgenogram shows a typical punch-press injury. The little finger was completely nonviable distal to the proximal phalanx. The middle joint of the ring finger was shattered, but the remaining fragments of the proximal and middle phalanges were adaptable to recession surgery.

Fig. 1-B: The remaining joint capsule of the middle phalanx was sutured to the transverse fibers of the proximal joint capsule with buried stainless-steel wire. Roentgenogram made one year after injury shows good union.

FIG. 1-C

FIG. 1-D

FIG. 1-E

Fig. 1-C: Photograph taken four months after injury shows the acceptable cosmetic appearance of the finger with a normal nail. The soft-tissue bulge of the neurovascular arch can be seen on the radial aspect.

Fig. 1-D: Photograph demonstrates good extension of the recessed finger and a pleasing conformity to the hand.

Fig. 1-E: Photograph taken eight months after surgery shows the patient's ability to grasp a hammer.

areas with exposed bone or tendons are promptly covered by soft-tissue flaps or split-skin grafts taken from the volar surface of the forearm. As healing progresses, the soft-tissue bunching gradually recedes, and, in twelve to sixteen weeks, the finger shows more symmetrical conformity.

A fluff-gauze dressing is applied and the fingers are fixed in a position of function on a volar plaster splint extending from the finger tips to the upper third of the forearm. Uninjured digits are not incorporated in the dressings, but are left unrestricted, so as to avoid the atrophy of disuse. A stockinette bandage holds the splint in place and exerts constant moderate pressure on the soft tissues, the maximum pressure being at the finger tips and diminishing proximally. Prophylactic antitetanic medication follows surgical repair. An initial dose of 1,000,000 units of penicillin is administered; doses of 600,000 units are given for the next five to seven days, or as indicated.

FIG. 2-A

The postoperative course is generally uneventful. As long as there is no abnormal elevation in temperature, the wounds are not disturbed. At the end of three or four weeks, the dressings are changed and the skin sutures are removed. The splint is reapplied for another three or four weeks, after which the Kirschner wires are removed. For this procedure, a novocain wheal is adequate, since there is very little discomfort. Roentgenographic examination at this time shows little bony callus. However, if the site of bone approximation

FIG. 2-B

FIG. 2-C

Fig. 2-A: Roentgenogram demonstrates a mutilating injury to the left hand. The only digit suitable for recession surgery was the ring finger.

Fig. 2-B: Postoperative roentgenogram shows the Kirschner wire lying along the volar surface of the distal phalanx and through the middle phalanx, fixing the impacted fragments. The transverse metacarpal arch was preserved to maintain strength of the hand.

Fig. 2-C: Roentgenogram made six weeks after injury shows good bony union with slight volar flexion. The roughened bone edges became smooth within twelve months and presented no problem.

FIG. 2-D

FIG. 2-E

Fig. 2-D: Photograph demonstrates a good grasp. Had the ring finger been amputated, a weak grasp would have resulted.

Fig. 2-E: The almost normal appearance of the recessed ring finger is noteworthy.

demonstrates good clinical union, only a restrictive bandage is needed; if false motion is present, the splint is re-applied until clinical union is achieved. Finger excursion is encouraged as soon as there is clinical stability to permit it. Physical therapy in the form of whirlpool baths seems to aid in regaining early movement; however, there is no kind of physical therapy that can replace early voluntary use of the hand. Return to work within eight to twelve weeks is urged.

REPORT OF CASES

The following case reports are representative of the group treated and have been selected as illustrating the principles of surgical repair outlined:

CASE 1. Mr. A . . . h, aged twenty, caught his left (major) hand in a punch press. There was almost complete destruction of the little finger, and the ring finger, contused and crushed, presented multiple comminuted fractures of the proximal phalanx with complete destruction of the middle joint (Fig. 1-A). Before surgery, he was given 100 milligrams of demerol and a digital nerve block with 2 per cent. novocain.

Surgical treatment consisted of a meticulous débridement. The little finger was amputated through the proximal phalanx. In the ring finger, the middle and distal phalanges were viable, and it was felt that a recession operation was indicated. On the radial side of the finger, the digital nerve and vessels were contused but intact. On the ulnar side, the blood and nerve supplies were completely destroyed. The loose bone fragments were removed, and the middle phalanx was arthrodesed to the remaining portion of the proximal phalanx. Fixation was done with buried stainless-steel wire sutures passed through the remaining portion of the joint capsule (Fig. 1-B). (In later cases, this method was abandoned and intramedullary pins were used for better fixation.) The nerve to the ulnar side of the finger was repaired; bleeders were ligated; and, on the radial aspect of the finger, an arch was formed containing the digital nerve and blood vessels. The flexor and extensor tendons were left intact. The wounds were closed with interrupted stainless-steel wire.

The postoperative course was uneventful, and the patient resumed his regular work fourteen weeks after injury. Seventeen months later, his grip measured 90 kilograms, as compared with 130 kilograms on the right uninjured hand.* On flexion, the tip of the ring finger lacked one and one half inches of touching the mid-

* A spring type of dynamometer was used.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Roentgenogram reveals complete destruction of the distal joint of the middle finger. A flying piece of metal had produced an explosion type of destruction.

Fig. 3-B: Roentgenogram made after surgery shows Kirschner wires fixing the recessed phalanges.

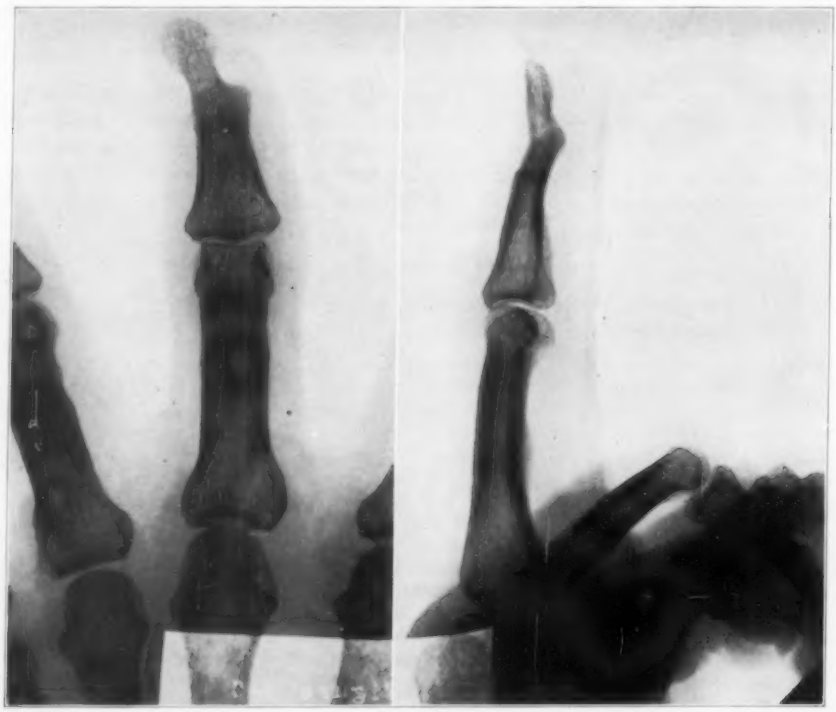

FIG. 3-C

Roentgenogram made eight weeks postoperatively demonstrates good bony union.

palmar crease, the proximal joint flexing to make an angle of 88 degrees and the distal joint an angle at 15 degrees. Extension was complete. The patient demonstrated good sensation and stereognosis, but stated that he had some numbness on the ulnar aspect of the distal phalanx. The fingernail was normal in appearance and growth and the hand was acceptable cosmetically (Figs. 1-C and 1-D). He could hold objects, such as a hammer, iron bars, and plates (Fig. 1-E).

FIG. 3-D

The middle finger appears normal except for some shortening. The patient demonstrates good grasping ability in holding a hammer.

CASE 2. Mr. W., aged thirty-nine, caught his left hand in a press of a stamping plant in such a way that the index finger was amputated through the proximal phalanx and the entire middle finger was destroyed, including its proximal joint. In an area in the palm, approximately two inches in diameter, the flexor tendons were exposed. In the ring finger, there was an open comminuted fracture of the distal phalanx with destruction of the distal joint and avulsion of the flexor-tendon insertion. There were multiple contused lacerations on the volar surface of the middle and distal segments of the fingers (Fig. 2-A).

Meticulous débridement was carried out. The stump of the index finger was revised. The middle finger was filleted, the bone was resected through the distal end of the metacarpal, leaving sufficient length to maintain the transverse metacarpal arch, and the filleted tissue was used to cover the palmar defect. In the ring finger, the bony fragments of the distal phalanx and of the joint were removed, as was the remaining articular cartilage. Then the distal phalanx was impacted with the middle phalanx and fixed by a Kirschner wire passed through the dense fibrous tissue of the distal phalanx and into the middle phalanx intramedullarly. With the exception of the flexor profundus tendon, all of the nerves, vessels, and tendons were intact. The wounds were closed with stainless-steel wire sutures (Fig. 2-B).

The postoperative course was uneventful, and the patient returned to his regular work six weeks after injury. Roentgenographic examination showed good bony union (Fig. 2-C). Ten months after injury, his grip was 60 kilograms, as compared to 155 kilograms on the right (major) hand. Extension was complete except for the distal joint, which was ankylosed in 40 degrees of flexion. The proximal joint could be flexed 85 degrees, the middle joint 100, and the tip of the finger could be flexed to within three quarters of an inch of the mid-palmar crease. The arthrodesis was stable, and the soft tissue had good sensation with only a slight amount of tenderness of the scarred area. The appearance of the finger was good. The nail was intact and normal in appearance (Figs. 2-D and 2-E).

CASE 3. Mr. L., a fifty-year-old metal polisher, injured his left middle finger on a piece of flying metal. There were complete destruction of the distal joint (Fig. 3-A), open comminuted fractures of the adjacent phalanges, and multiple lacerations and contusions of the soft tissue. The neurovascular bundles and the tendons were intact.

Careful débridement was done under avascular conditions. Because the ends of the phalanges were oblique and tapered, the arthrodesis was fixed by Kirschner wires placed at right angles to the fracture lines rather than intramedullarly (Fig. 3-B). There was slight bilateral bulging of the neurovascular bridges. The tendons were not disturbed. Immobilization was confined to the injured finger, and the patient returned to work the following day where he was able to use the free fingers of the injured hand, as well as of the uninjured hand. His progress was uncomplicated. Roentgenographic examination made eight weeks later demonstrated good bony union (Fig. 3-C). The angulation and slight dorsal displacement did not restrict function.

Examination after two years demonstrated a cosmetically good finger. The color and sensation were normal. The nail had normal texture and growth. The patient had been doing his regular job as a metal

polisher, experiencing no difficulty. He could pick up small objects, such as matches and pins, with the thumb and long finger. He stated that his friends had noticed no abnormality of his hand (Fig. 3-D). The finger was half an inch shorter than that of the uninjured hand. The distal joint was fused and motions of the remaining joints were normal. There was no loss of grip.

FIG. 4-A

CASE 4. Mr. C., aged forty-three, a trash collector, caught his right hand between a telephone pole and the door of his moving truck. He was found to have avulsion of the soft tissues and an open comminuted fracture of the distal phalanx of the index finger, as well as an open comminuted fracture of the middle phalanx of the middle finger with considerable bone loss and marked displacement of the fragments. The adjacent joints were intact. There was marked soft-tissue damage and the nerve on the radial side was severed, as were the blood vessels. A laceration into the middle joint of the ring finger destroyed the radial aspect of the joint capsule and a portion of the extensor tendon (Fig. 4-A).

Fig. 4-A: Roentgenogram demonstrates an injury ideally suited to recession surgery. The middle finger has suffered a shattering open comminuted fracture of the middle phalanx with loss of bone substance, but the adjacent joints are intact. There is sufficient bone remaining to permit limited bone repair.

Fig. 4-B: Postoperative roentgenographic examination demonstrates intramedullary Kirschner-wire fixation with almost anatomical alignment. There is enough bone substance on each side of the recession site to ensure solid anchorage.

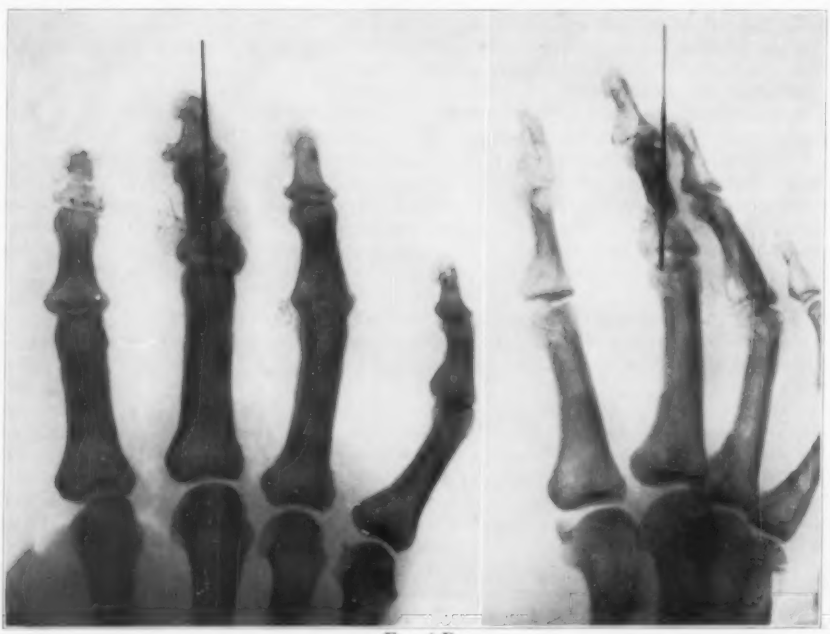

FIG. 4-B

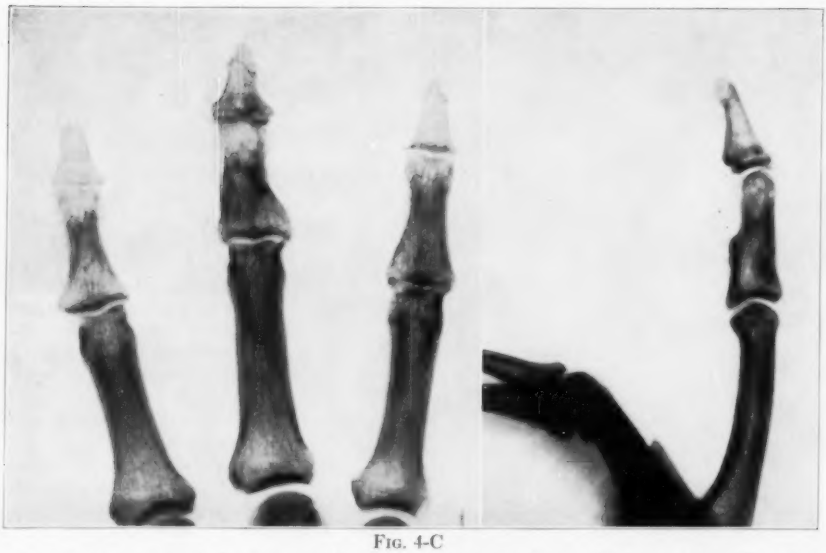

FIG. 4-C

Roentgenograms made fourteen months after injury demonstrate solid bony union. The phalanx is shortened and thickened, but presents good alignment. Joint spaces are normal, as compared with those of the uninjured fingers.

A sedative was given and the patient was prepared for surgery. Following a 2 per cent. novocain nerve block, careful débridement was accomplished, and the wounds of the index finger were repaired with stainless-steel wire. In the middle finger, the loose bone fragments were removed, and the remaining distal portion was impacted with the proximal third and fixed by an intramedullary Kirschner wire. The severed digital nerve was resected to vital tissue and repaired. The skin was closed with stainless-steel wire sutures (Fig. 4-B). The postoperative course was uneventful. Roentgenographic examination six weeks later showed healing and good alignment at the recessed site.

Examination fourteen months after injury revealed a grip reading of 88 kilograms, as compared with 100 kilograms in the uninjured left hand. On flexion, the middle finger lacked one and one-half inches of touching the mid-palmar crease, the proximal joint flexing 70 to 80 degrees, the middle joint 61 to 106 degrees, and the distal joint 20 to 63 degrees. The finger was half an inch shorter than that on the opposite uninjured hand. Sensation was normal except for slightly diminished acuity over the distal phalanx. The nail was normal in appearance, growth, and color. The patient was doing his regular job of trash collecting, which placed a heavy strain on the hand. He had a history of painful arthritis affecting both hands. Other than this, he had no complaints and he was happy with the recessed finger and grateful that an amputation had not been necessary (Fig. 4-C).

CASE 5. Mr. A . . . l, aged forty-five, caught his left hand in a trim saw. The little finger was amputated through the distal joint and the ring finger through the proximal phalanx. In the middle finger, there were open comminuted fractures of the proximal and middle phalanges, with complete destruction of the middle joint. Both digital nerves were severed, as were the artery and the vein on the ulnar side of the finger; the nerves and blood vessels on the radial side of the finger were intact. The index finger suffered an identical injury except that the nerve on the radial side was spared. In both fingers, much bone tissue was lost. In the thumb, there was an open comminuted fracture of the distal phalanx (Fig. 5-A).

Following surgical preparation and a nerve block, a careful débridement was done, as well as a revision of the little and ring fingers and a plastic repair of the thumb with a skin graft. In the middle finger, the loose bone fragments were removed and an arthrodesis was done, the bones being fixed by an intramedullary Kirschner wire. The severed nerves were repaired and the skin was closed with stainless-steel wire sutures. Bone fragments of the index finger were removed, and the middle and proximal phalanges were impacted and pinned with intramedullary wire (Fig. 5-B). Partially severed tendons were debrided but not resected. It was necessary to apply a split-skin graft to a denuded area approximately one inch by one-half inch, over the site of recession. Viability of the recessed fingers was questionable at the time of surgery, but the patient had an uneventful postoperative course. He returned to light work nine weeks after injury and to his regular job at the mill thirteen weeks from the date of injury.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Roentgenogram made immediately following injury displays a completely shattered group of fingers. The distal phalanges of the little and ring fingers were amputated. Large bony defects appear in the middle and index fingers. Amputation of these fingers would have resulted in an almost useless appendage. In such an injury, phalangeal-recession surgery can be utilized to its fullest benefit.

Fig. 5-B: Postoperative roentgenogram shows the Kirschner wires in place. Bone repair was held to a minimum in order to preserve length. The site of arthrodesis represents the normal line of amputation if phalangeal recession had not been used. Bunching of the soft tissues can be seen, especially in the middle finger.

Examination at the eighth postoperative month showed flexion of the proximal joint of the index finger to be 75 to 81 degrees, that of the middle finger 75 to 90 degrees. Each finger lacked one and one half inches of touching the midpalmar crease. Extension was complete in the proximal joints. The distal joint of the index finger was fixed at 35 degrees of flexion and that of the middle finger at 40 degrees (Figs. 5-C and 5-D). The average grip for the left injured hand was 12 kilograms, for the right (major) hand, 101 kilograms. The index finger was half an inch shorter, the middle finger one and one-eighth inches shorter, than those of the opposite hand. The patient stated that he was able to hold his job and perform his regular duties. He could pick up nails and hold a hammer and board with the injured hand (Fig. 5-E). Roentgenographic examination demonstrated good callus formation (Fig. 5-F).

RESULTS

The results of this study would indicate that the primary finger recession has a definite place in the treatment of finger injuries. Each patient presented a specific problem, which was evaluated in terms of the trauma present. While the basic principle of phalangeal recession was applied in each case, the surgical approach was varied according to the trauma present. The results have been acceptable clinically, functionally, and psychologically. Postoperative complications, such as osteomyelitis, non-union, gangrene, causalgia, and marked atrophic changes, did not occur. On the contrary, all of the patients demonstrated healing *per primam*. Arthrodesed phalanges did not require a longer period of healing than did simple fractures. The time the patient was absent from work was not longer than that necessary for an amputation, and the permanent disability was much less. Revisionary surgical procedures were not done, nor were they indicated in this group. All of the patients returned to their regular work and have continued in it to date. The satisfactory results are directly attributable to the strictest adherence to the principles governing hand surgery, to the fact that repair

FIG. 5-C

FIG. 5-D

FIG. 5-E

Fig. 5-C: Photographs taken eight months after operation illustrate a good pinching mechanism. The index finger with its special stereognostic sense can approximate the thumb, enabling the patient to handle small objects.

Fig. 5-D: A good range of extension is demonstrated. Considerable length of the index and middle fingers has been preserved.

Fig. 5-E: Photograph taken eight months postoperatively shows the patient's ability to hold such large objects as a hammer. He can also pick up matches and pins.

Fig. 5-F: Roentgenogram made twenty months after operation shows good bony union and anatomical alignment.

was undertaken within the first six hours, and to antibiotic therapy.

FIG. 5-F

DISCUSSION

Phalangeal-recession surgery is indicated where gross portions of bone and soft tissue are lost. A soft-tissue bridge containing the digital artery and nerve or a reparable nerve is essential for tissue viability distal to the wound. The gap is closed by fixing the distal bone fragment to the proximal one with Kirschner wire. The resulting finger is shorter than normal, but demonstrates good motion, sensation, and cosmetic appearance. Motion in the fingers varies with the amount of damage. When only the distal joint has been destroyed, good motion is obtained by

the action of the proximal and middle joints. With destruction of both middle and distal joints, motion is restricted to the proximal joint. Destruction confined to the middle joint permits motion of the proximal and occasionally of the distal joint. Other factors, such as the presence or absence of tendons and the amount of trauma suffered by the tendons and their gliding mechanisms, also determine the degree of motion.

The hand is an organ of irreplaceable function. No prosthesis has yet been devised to fulfill the functional requirements of prehension, sensation, and expression demonstrated by the normal hand. It follows that a maximum effort must be expended to salvage all the remaining viable parts of the injured extremity. In most cases of hand injuries, it lies within the realm and skill of the first surgeon seen by the patient to restore a useful member — a hand which will enable him to make a living. Bunnell[1] states: "The outlook for the injured hand, as to whether it is doomed to disability or will regain useful function, depends primarily on the first aid and early definitive treatment rather than upon the care during convalescence".

CONCLUSIONS

1. Injuries to the fingers involving large gaps of soft-tissue and bone damage can be repaired by phalangeal recession, thus avoiding unnecessary amputation of the fingers.

2. The distal phalanx with its highly specialized sensation and stereognosis, its nail, and general cosmetic appearance can be salvaged.

3. The fundamental functions of the normal hand—prehension, sensation, and expression—are better salvaged by phalangeal-recession surgery than by amputation.

1. Bunnell, Sterling: The Early Treatment of Hand Injuries. J. Bone and Joint Surg., **33-A:** 807–811, July 1951.

DISCUSSION

The Internal Architecture of the Femur and Its Clinical Significance

(*Continued from page 77*)

and the split-line technique which I have mentioned, is now underway; these should add further information to Dr. Tobin's work. May I compliment him upon his paper and upon his fine photography.

a. Benninghof, A.: Spaltlinien am Knochen, eine Methode zur Ermittlung der Architektur platter Knochen. Verhandl. d. Anat. Gesellsch., **34:** 189–206, 1925.

b. Evans, F. G.; Hayes, J. F.; and Powers, J. E.: "Stresscoat" Deformation Studies of the Human Femur under Transverse Loading. Anat. Rec., **116:** 171–188, 1953.

c. Flourens, P.: Théorie Expérimentale de la Formation des Os. Paris, J.-B. Baillière, 1847.

d. Haboush, E. J.: Photoelastic Stress and Strain Analysis in Cervical Fractures of the Femur. Bull. Hosp. Joint Dis., **13:** 252–258, 1952.

e. Haboush, E. J.: Biomechanics of Femoral Nail and Nailplate Insertions in Fractures of the Neck of the Femur. Bull. Hosp. Joint Dis., **14:** 125–137, 1953.

f. Roux, Wilhelm: Der Kampf der Theile im Organismus. Ein Beitrag zur Vervollständigung der Mechanischen Zweckmässigkeitslehre. Leipzig, Wilhelm Engelmann, 1881.

g. Spray, C. M., and Widdowson, E. M.: The Effect of Growth and Development on the Composition of Mammals. British J. Nutrit., **4:** 332–353, 1950.

h. Tappen, N. C.: A Functional Analysis of the Facial Skeleton with Split-Line Technique. Am. J. Phys. Anthropol., **11:** 503–532, 1953.

Dr. Tobin (closing): Dr. Haboush has discussed the internal architecture of the femur from the biomechanical viewpoint. Dr. Goff has approached the material presented from the comparative anatomical and anthropological aspects. I, too, am interested in anthropology. An attempt has been made to present the architecture of the upper end of the femur from the clincial point of view.

THE MECHANISM OF TOTAL DISLOCATION OF THE TALUS

BY BALDO LEITNER, M.D., VIENNA, AUSTRIA

*From the Unfallkrankenhaus, Wien**

The mechanism of total dislocation of the talus is not well understood and there has been much difference of opinion about it. In 1944, Kirschner and Nordmann wrote that the mechanism of the injury was not understood. Watson-Jones, in 1943, classified total dislocation of the talus as a third-degree inversion injury; he classified dislocation of the ankle joint as a first-degree inversion injury and dislocation of the subtalar joint as a second-degree inversion injury (see his Figs. 1226 to 1228). Bonnin, in 1950, called it splitting hairs to argue about which joint dislocates first. What, then, is the real mechanism of this dislocation, and which joint dislocates first?

The many contradictory explanations in the literature do not answer these questions. The key to the solution lies in the study of the mechanism of the subtalar dislocation. In a review of forty-two recent cases of this injury, the author found a concomitant subluxation of the ankle joint in six patients. Böhler considered this lesion to represent a preliminary stage in total dislocation of the talus. The diagnosis of talocrural dislocation in these cases was purely accidental. If special attention had been paid to it—for example, by making x-rays under strain—the concomitant talocrural subluxation would probably have been found more often. In these severe injuries the force of the blow damaged the ligaments, not only of the subtalar joint, but also of the ankle joint.

Cases of subtalar dislocation with concomitant subluxation of the ankle joint (ranging from preliminary stages to total dislocation of the talus) are shown in Figures 2-A to 2-C, 5-A and 5-B, and Figure 8, *1b* and *2b*.

The extent of subluxation of the ankle joint may vary from slight displacement to almost complete dislocation. The clinical appearance in these preliminary stages is almost identical with that in medial and lateral subtalar dislocation, that is, maximum inversion

FIG. 1-A FIG. 1-B

Medial subtalar dislocation.

Fig. 1-A: Subtalar displacement by half the width of the talus (see also Fig. 8, *1a*).

Fig. 1-B: Note the gap between the talus and the calcaneus.

* Direktor: Prof. Lorenz Böhler.

FIG. 2-A

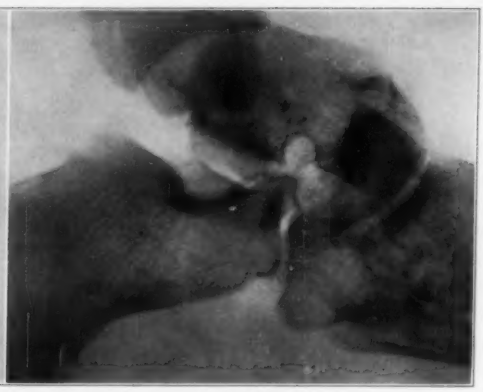

FIG. 2-B

FIG. 2-C

Figs. 2-A to 2-C: Medial subtalar dislocation with anterior subluxation of the talus in the direction of supination. This is a preliminary stage in total medial dislocation of the talus.

Fig. 2-A: Medial subtalar dislocation with pronounced supination-subluxation of the ankle joint (see also Fig. 8, *1b*). (Reproduced by permission from *Ergebnisse der Chirurgie und Orthopädie*, **38**: 112, 1953.)

Fig. 2-B: The lateral view shows anterior subluxation of the talus, as well as the gap between the talus and the calcaneus. Note the fracture of the processus posterior tali. (Reproduced by permission from *Ergebnisse der Chirurgie und Orthopädie*, **38**: 112, 1953.)

Fig. 2-C: Dorsoplantar view, showing subluxation of the talus. This x-ray offers strong evidence that the lesion is a preliminary stage in total dislocation of the talus.

(supination) or eversion (pronation) of the foot. The subluxation of the ankle joint will hardly be detectable clinically. As a result of the force which causes medial subtalar dislocation, the foot is inverted, the head of the talus loses its contact with the navicular (subtalar dislocation), and finally the talocrural joint subluxates. The strongly inverted foot then loses its stability and glides back to a neutral position. Thus in medial subtalar dislocation with concomitant talocrural subluxation (Figs. 2-A to 2-C, and Fig. 8, *1b*) the foot is displaced further medially and is supinated to a lesser extent than in medial subtalar dislocation without accompanying subluxation of the talocrural joint (Figs. 1-A and 1-B, and Fig. 8, *1a*). In lateral subtalar dislocation with concomitant talocrural subluxation, the foot is in maximum pronation, so that the talus is dislodged from its normal position (Figs. 5-A and 5-B, and Fig. 8, *2b*). In lateral subtalar dislocation without talocrural subluxation (Figs. 4-A and 4-B, and Fig. 8, *2a*) the foot is less pronated and the lateral displacement occasionally is more evident. Abduction of the foot is exceptional. In our five cases of lateral subtalar dislocation there was clinical evidence of abduction in one case; adduction was present in two cases and the neutral position in two. This deformity is mainly caused by the subtalar dislocation. In total dislocation of the talus the main deformity disappears, as the talus is no longer impacted.

In reviewing his own roentgenograms and those in published reports [1,7,8,11,12,15,18,19,20]

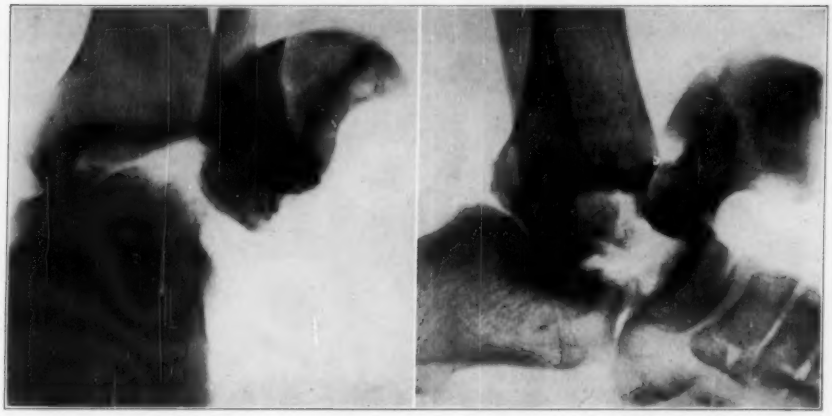

FIG. 3-A FIG. 3-B

Complete dislocation of the talus (open) by the mechanism of supination.

Fig. 3-A: Lateral dislocation of the talus by its full width (see also Fig. 8, *1c*). (Reproduced by permission from *Ergebnisse der Chirurgie und Orthopädie*, **38**: 120, 1953.)

Fig. 3-B: Anterior dislocation of the talus by its full width. Rotation of the talus about all three axes, so that its head (between the lower anterior margin of the tibia and the navicular) faces toward the heel and sole of the foot, whereas the body of the talus faces toward the toes and upward. (Reproduced by permission from *Ergebnisse der Chirurgie und Orthopädie*, **38**: 120, 1953.)

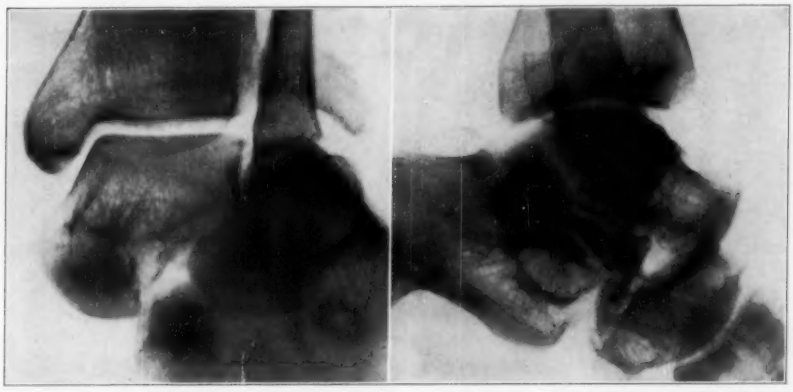

FIG. 4-A FIG. 4-B

Lateral subtalar dislocation.

Fig. 4-A: Lateral subtalar subluxation by the full width of the talus (see also Fig. 8, *2a*) and fracture of the lateral malleolus with upward displacement.

Fig. 4-B: Plantar and posterior subtalar dislocation and fracture of the processus posterior tali.

the author noted the gradual transition from a medial or lateral dislocation to total dislocation of the talus. There is no specific mechanism of trauma which leads to total dislocation of the talus, but the injuring force is stronger and acts over a longer period. The force, after having caused the subtalar dislocation, continues, ruptures the ligaments of the ankle joint, and finally forces the talus out of its normal place.

Subtalar dislocation is to be considered, as has been stated, as a preliminary stage in total dislocation of the talus. In primary dislocation at the talocrural joint—Ehalt, in 1947, called this injury "luxatio pedis cum talo"—when the talus is fixed to the foot, it is not probable that the talus will be separated from the foot as the traumatic force continues. The ligaments which hold the talus to the foot are stronger than those by which it is attached to the malleoli. Total dislocation of the talus may result either from

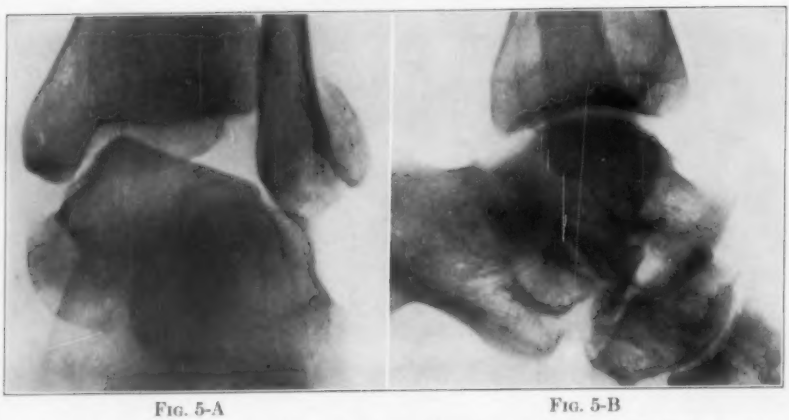

FIG. 5-A FIG. 5-B

Lateral subtalar dislocation with supination-subluxation of the talus. (Preliminary stage to total lateral dislocation of the talus.)

FIG. 6-A FIG. 6-B

Complete medial dislocation of the talus (open) by the mechanism of pronation.

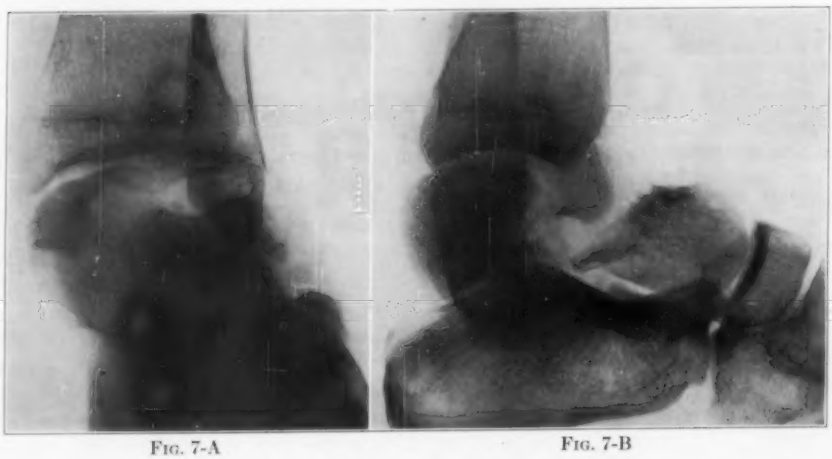

FIG. 7-A FIG. 7-B

Subtalar dislocation with fracture of the neck of the talus.

Fig. 5-A: Lateral subtalar dislocation with pronounced supination-subluxation of the ankle joint (see also Fig. 8, *2b*) and fracture of the lateral malleolus with upward displacement. (Reproduced by permission from *Ergebnisse der Chirurgie und Orthopädie*, **38**: 117, 1953.)

Fig. 5-B: Plantar and posterior subtalar dislocation with fracture of the processus posterior tali. (Reproduced by permission from *Ergebnisse der Chirurgie und Orthopädie*, **38**: 117, 1953.)

Fig. 6-A: Medial dislocation of the talus by its full width (see also Fig. 8, *2c*). The trochlea tali faces medially and downward. There is also a fracture of the lateral malleolus. (Courtesy of Prof. Pachner, Genoa, Italy.)

Fig. 6-B: The talus is dislocated exactly medially. The head of the talus faces the toes. (Courtesy of Prof. Pachner, Genoa, Italy.)

Fig. 7-A: Lateral displacement of the foot, the head of the talus being displaced by half the width of the talus. The body of the talus is rotated around its long axis through 45 degrees (pronation-subluxation), so that the trochlea tali faces medially and upward and the lower joint surface of the talus faces laterally and downward.

Fig. 7-B: Anterior displacement of the foot, the head of the talus being displaced about two centimeters. The fragment from the body of the talus is rotated backward around a horizontal axis through about 25 degrees. A fragment of the lateral malleolus is visible between the fragments of the talus.

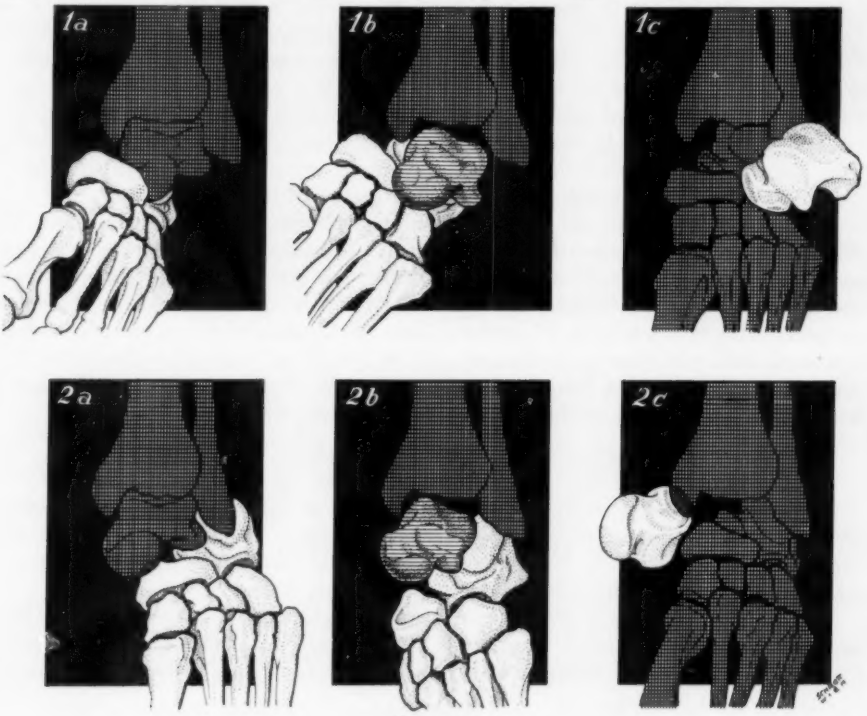

FIG. 8

Drawings of the luxation mechanisms leading to total dislocation of the talus.

Fig. 8, *1a:* Total dislocation of the talus by a supinatory force, first degree: medial subtalar dislocation (see also Fig. 1-A).

Fig. 8, *1b:* Total dislocation of the talus by a supinatory force, second degree: medial subtalar dislocation with supination-subluxation of the talus (see also Fig. 2-A).

Fig. 8, *1c:* Total dislocation of the talus by a supinatory force, third degree: total lateral dislocation of the talus (see also Fig. 3-A).

Fig. 8, *2a:* Total dislocation of the talus by a pronatory force, first degree: lateral subtalar dislocation (see also Fig. 4-A).

Fig. 8, *2b:* Total dislocation of the talus by a pronatory force, second degree: lateral subtalar dislocation with supination-subluxation of the talus (see also Fig. 5-A).

Fig. 8, *2c:* Total dislocation of the talus by a pronatory force, third degree: total medial dislocation of the talus (see also Fig. 6-A).

excessive inversion or from excessive eversion of the foot. In the preliminary stages of total medial dislocation—that is, medial subtalar dislocation with talocrural subluxation—

supination or anterior subluxation is seen; pronation-subluxation of the talus is never found. The reason for this is evident, as the nature of the trauma leads to forced supination. It is surprising, however, that the *lateral* preliminary stages of total dislocation—that is, lateral subtalar dislocation with talocrural subluxation—also reveal a supination-subluxation of the talus, never a pronation-subluxation. How can this fact be explained?

As the injury results from forced pronation of the foot, it is to be expected that the talus subluxates in pronation. A pronation-subluxation of the talus has never been found in our cases, however; the cases reported by Benedetti-Valentini and by Pfaehler also showed supination-subluxation of the talus. From experiments on cadavera it is evident that the talus can easily luxate laterally in supination. The medial malleolus and the calcaneus act as obstacles when the talus is forced to luxate medially with the foot in pronation. Only if the talus rotates as in supination can it glide out of its position medially. This may be seen in Figures 6-A and 6-B, and Fig. 8, *2c*. The anteroposterior view shows the talus in supination, the trochlea facing laterally. In one of the author's cases of total fracture-dislocation of the talus the trochlea faced medially and plantarward. In lateral subtalar dislocation with fracture of the neck or body of the talus the fragment from the body is pronated (pronation-subluxation of the body of the talus) because the foot is dislocated further laterally and because the luxating fragment is smaller than the talus (Figs. 7-A and 7-B). This corresponds with the reports of Ogilvy in 1927 (see his Fig. 1), Peter in 1933 (his Fig. 1), and Watson-Jones in 1943 (his Fig. 1253).

In total dislocation of the talus the position of the talus reveals at once whether supination or pronation caused the dislocation. A supination mechanism forces the talus medialward. The supination mechanism occurs much more frequently than the pronation mechanism. At the *Unfallkrankenhaus* we have treated thirty-six cases of medial as compared with only five cases of lateral subtalar dislocation, and four cases of medial as compared with two cases of preliminary lateral stages in total dislocation of the talus (subtalar dislocation with talocrural subluxation). With the pronation mechanism the lateral malleolus is often fractured (Figs. 4-A, 5-A, and 6-A).

SUMMARY

Total dislocation of the talus results either from excessive supination or from excessive pronation; accordingly the dislocated talus lies either laterally or medially. A first-degree supination injury results in medial subtalar dislocation; a second-degree supination injury results in medial subtalar dislocation with talocrural subluxation; and a third-degree supination injury results in total lateral dislocation of the talus.

A first-degree pronation injury results in lateral subtalar dislocation; a second-degree pronation injury results in lateral subtalar dislocation, together with talocrural subluxation; and a third-degree pronation injury results in total medial dislocation of the talus.

REFERENCES

1. Bard: Luxation double de l'astragale. Lyon Chir., **42:** 747–748, 1947.
2. Benedetti-Valentini, F.: Considerazioni sulla patogenesi e sulla terapia delle lussazioni isolate dell'astragalo (Lavoro clinico-sperimentale). Policlinico, Sez. Chir., **38:** 525–540, 1931.
3. Böhler, Lorenz: Technik der Knochenbruchbehandlung im Frieden und im Kriege. Aufl. 9–11, Band 2, S. 1383. Wien, Wilhelm Maudrich, 1943.
4. Bonnin, J. G.: Dislocations and Fracture-Dislocations of Talus. British J. Surg., **28:** 88–100, 1940.
5. Bonnin, J. G.: Injuries to the Ankle, pp. 324–380. New York, Grune and Stratton, 1950.
6. Ehalt, Walther: Luxatio pedis cum talo. Klin. Med. (Wien), **2:** 725–729, 1947.
7. Goldammer: Zur Kasuistik seltener Talusverletzungen. Beitr. Klin. Chir., **92:** 710–728, 1914.
8. Gröss, Emil: Drei seltene Luxationen am Fuss. Der Chirurg, **11:** 560–565, 1939.
9. Kirschner, M., und Nordmann, O.: Die Chirurgie. Band 4, S. 1043. Berlin, Urban und Schwarzenberg, 1944.
10. Leitner, Baldo: Die Totalluxation des Talus und ihre Vorstufen. Ergeb. d. Chir. u. Orthop., **38:** 93–135, 1952.
11. Mitchell, J. I.: Total Dislocation of the Astragalus. J. Bone and Joint Surg., **18:** 212–214, Jan. 1936.

12. Newcomb, W. J., and Brav, E. A.: Complete Dislocation of the Talus. J. Bone and Joint Surg., **30-A**: 872–874, Oct. 1948.
13. Ogilvy, Charles: Postoperative Result in a Case of Dislocation of the Ankle with Fracture and Avulsion of the Head of the Astragalus. Am. J. Surg., **2**: 508–510, 1927.
14. Ollerenshaw, Robert: Rotation-Dislocation of the Astragalus. British Med. J., **1**: 155–156, 1921.
15. Pekarek, Franz: Zur Frage der subkutanen Luxation des Talus und ihrer Reposition. Münchener Med. Wochenschr., **74**: 1095–1097, 1927.
16. Peter, Erwin: Zur Talusluxationsfraktur. Zentralbl. f. Chir., **60**: 1055–1057, 1933.
17. Pfaehler, Paul: Zur Luxatio tali totalis. Schweizerische Med. Wochnschr., **12**: 768–769, 1931.
18. Scharsich, K.: Isolierte, unkomplizierte Talusluxation. Zentralbl. f. Chir., **57**: 2626, 1930.
19. Scharsich, K.: Isolierte unkomplizierte Talusluxation. Beitr. Klin. Chir., **151**: 566–568, 1931.
20. Sneed, W. L.: The Astragalus: A Case of Dislocation, Excision, and Replacement. An Attempt to Demonstrate the Circulation in This Bone. J. Bone and Joint Surg., **7**: 384–399, Apr. 1925.
21. Watson-Jones, R.: Fractures and Joint Injuries. Ed. 3, vol. 2, pp. 822–829, 838. Baltimore, The Williams and Wilkins Co., 1943.

INTERMITTENT COMPRESSION ARTHRODESIS OF THE KNEE

A Preliminary Report

BY DR. GAWAD HAMADA, ALEXANDRIA, EGYPT

Impaction of bony fragments, whether produced by the initial injury, by body weight, or by mechanical compression, plays an important role in promoting the formation of early callus and union in the healing of fractures. Patients with impacted abduction subcapital fractures of the neck of the femur may be allowed early mobility, with the result that further impaction occurs and union is rapid. Early movement and use of the hand in impacted Colles' fracture will shorten convalescence and hasten union. While impaction and interlocking of raw areas of cancellous bone are conducive to early union, separation of fragments results in non-union or delayed union. The space to be filled at the fracture site, where there is firm contact, is small and permits the rapid intermingling of the osteoblastic tissue of both fragments. In separated fragments, on the other hand, there is a gap and the hematoma is larger. Rotatory and side-to-side movements are greater when compression is lacking and are therefore liable to disturb the intervening blood clot with its ingrowing capillaries and osteoblastic tissue.

Early mobility and use of the limb not only prevent disuse atrophy, but check the initial local oedema and congestion about the fractured fragments. This augments the supply of important osteogenetic factors necessary to bone formation which are carried in the blood stream.

Various methods of skeletal fixation by different types of nails have been described

for fractures and for arthrodeses of excised joints, to prevent mobility and displacement of fragments. Key in 1932 was the first to use compression to keep the denuded bony surfaces of the knee in position and so to encourage early fusion. After treating five cases with success, Key abandoned the method. Charnley [2] in 1948 revived this technique and has treated one hundred cases [3] with only two "complete failures".

To ensure correct coaptation of the fragments with stability, and to help compression or contact of the raw bone surfaces of the knee joint, either the Charnley compressor or an intramedullary Küntscher nail [1,5] is used. The author has used the latter method with success.

OPERATIVE TECHNIQUE

A semicircular incision is made over the knee, cutting down through all the tissues to the joint. The knee is flexed and, with a saw or a broad chisel, all diseased bone and cartilage are removed until two flat, healthy cancellous surfaces are left to fit closely in apposition. A second incision is made over the middle of the tibia. The muscles of the anterior compartment of the leg are detached subperiosteally and retracted laterally. With a small gouge, a trough-shaped opening is made in the medullary cavity in the lateral aspect of the mid-portion of the tibia.

A clover-leaf Küntscher nail of proper size, with two centimeters of its blunt end bent to a right angle, is introduced through this tibial aperture and is driven upward toward the knee. It is directed toward the middle of the intercondylar area of the tibial plateau and, when it presents itself at this site, the knee is extended and so placed that the nail engages the center of the cut surface of the distal end of the femur. The nail is then driven up along the femoral shaft. It will be found to travel easily through the medullary canal. Its progress is resisted in the proximal part of the femur, where the canal becomes narrower. A few sharp taps with the hammer will impact the nail, if it is the correct size. The lower end of the nail is driven in until the bent part becomes caught in the tibial trough, thus preventing rotation. The nail, if it fits tightly above and below, will prevent flexion, extension, rotation, and angulation.

If necessary, cavities or spaces between the excised bone ends are filled with pieces of the patella.

The capsule and skin are sutured. The lower end of the nail is buried between the muscles and the tibia.

A plaster cast is applied from the toes to the upper part of the thigh. Three weeks after the operation, the patient is allowed out of bed and is made to walk. The average duration of plaster immobilization has been four months in our cases. The nail is removed three to six months after the operation, according to the state of union seen in the roentgenograms.

In our last two cases, ambulatory treatment without external fixation of the limb

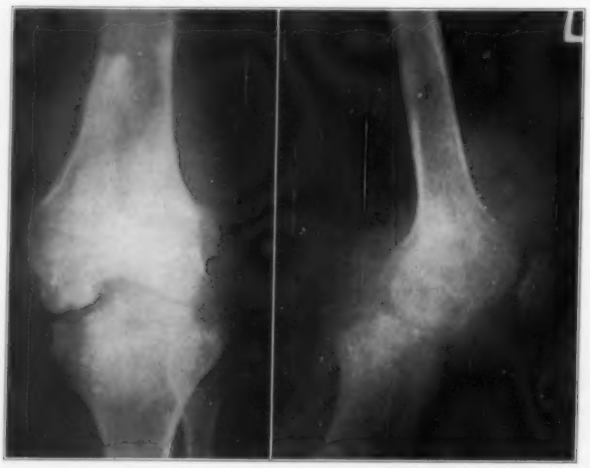

FIG. 1-A FIG. 1-B

Case 1, a patient with tuberculosis. Anteroposterior and lateral roentgenograms, made February 13, 1950, showing the condition before operation.

FIG. 2-A FIG. 2-B

FIG. 3-A FIG. 3-B

Figs. 2-A and 2-B: Anteroposterior and lateral roentgenograms made March 24, 1950, two days after insertion of an intramedullary nail.

Figs. 3-A and 3-B: Roentgenograms made October 11, 1953, a little more than three and a half years after operation, showed complete bony ankylosis.

was tried. Two weeks after the operation these patients were encouraged to walk; at first they supported themselves on the bed and in a few days they shuffled along, pushing a chair before them. The results in these two patients have been encouraging. The following are summaries of their records.

CASE 8. A man, aged thirty-five, had a subluxated knee joint with painful traumatic arthritis resulting from an old compound dislocation of the knee. The knee was excised and a Küntscher nail was introduced. The patella was cut into small pieces, which were placed between the excised fragments. The patient was allowed to walk two weeks after the operation without a plaster cast or a splint. Eighty-five days after the operation the nail was removed. The knee was clinically firm and the patient walked without pain. Twenty days later the roentgenograms showed an appreciable amount of bony union. The patient went back to his work as a clerk somewhat less than four months after operation.

CASE 9. A man, sixty-five years old, was admitted to the hospital with old suppurative arthritis and bony ankylosis of the knee at 90 degrees of flexion. A wedge of bone was removed from the ankylosed joint and an intramedullary nail was introduced to hold the two fragments straight. The patient started walking three weeks after the operation. At first he found it difficult, having been used to walking with a bent and fixed knee. He gradually adapted himself, however, and, after eight weeks, was walking unassisted without any pain.

DISCUSSION

Charnley [3] did not favor intramedullary nailing as a compression method. We believe, however, that compression results from weight-bearing when an intramedullary nail is used. The long leverage of the impacted nail prevents torsion or angulation.

We believe that, while continuous mechanical compression may produce pressure atrophy and necrosis of cancellous bone, intermittent compression is a stimulus to bone formation.

Charnley [3] referred to a patient of Mr. J. Dobson's "who had been treated for a number of years . . . on a Thomas frame for Pott's paraplegia. Owing to a permanent adductor spasm the external condyles of both his knee-joints had been compressed for so

TABLE I

SUMMARY OF CASES

Case	Age (*Years*)	Diagnosis	Date of Operation	Approximate Follow-up Period	Result	Remarks
1	27	Tuberculosis *	March 22, 1950	4 years	Good	Plaster fixation
2	35	Old suppurative arthritis *	April 5, 1950	4 years	Good	Plaster fixation
3	19	Tuberculosis *	April 25, 1950	4 years	Good	Plaster fixation
4	35	Tuberculosis	November 11, 1950	3 years	Good	Plaster fixation
5	30	Tuberculosis *	December 26, 1951	2 years	Good	Plaster fixation
6	22	Old suppurative arthritis *	April 22, 1952	2 years	Good	Plaster fixation
7	16	Tuberculosis *	June 10, 1952			Has left the country.
8	35	Compound dislocation	September 10, 1953	4 months	Good	No external fixation. Nail removed. Walks well.
9	65	Old suppurative arthritis, flexion deformity of 90 degrees	November 31, 1953	10 months	Good	No external splinting. Walks well unassisted.

* Lesion diagnosed by biopsy.

long that in one knee the articular cartilage ulcerated and true osseous union occurred spontaneously." Such spasm, however, cannot produce continuous compression, as no doubt there are periods of greater or lesser relaxation of the spasmodic muscle tension.

Excision of the knee with resultant flat, close-fitting surfaces creates a condition similar to a transverse fracture of the femur treated by an intramedullary nail.

This technique has been tried in various types of arthritis and has also given encouraging results in tuberculosis.

No complications have been observed in the cases here reported. In cases in which a fistula had formed around the lower end of the nail, the sinus closed soon after the nail had been removed.

REFERENCES

1. CHAPCHAL, GEORGE: Intramedullary Pinning for Arthrodesis of the Knee Joint. J. Bone and Joint Surg., **30-A:** 728–734, July 1948.
2. CHARNLEY, J. C.: Positive Pressure in Arthrodesis of the Knee Joint. J. Bone and Joint Surg., **30-B:** 478–486, Aug. 1948.
3. CHARNLEY, JOHN: Compression Arthrodesis. Including Central Dislocation as a Principle in Hip Surgery. Edinburgh, E. and S. Livingstone, 1953.
4. KEY, J. A.: Positive Pressure Arthrodesis for Tuberculosis of the Knee Joint. Southern Med. J., **25:** 909–915, 1932.
5. MORRIS, H. D., and MOSIMAN, R. S.: Arthrodesis of the Knee. A Comparison of the Compression Method with the Non-Compression Method. J. Bone and Joint Surg., **33-A:** 982–987, Oct. 1951.
6. PERKINS, GEORGE: Rest and Movement. J. Bone and Joint Surg., **35-B:** 521–539, Nov. 1953.

EXPERIENCES WITH THE PALMER OPEN REDUCTION OF FRACTURES OF THE CALCANEUS *

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In opening this paper, the authors wish to recognize the great variety of therapeutic approaches to the fractured calcaneus which have been described in the literature in recent years. Methods vary from simple control of oedema and early mobilization, as reported by Belenger, Vander Elst, and Lorthioir and Carothers and Lyons, through a primary or early subtalar arthrodesis according to the techniques designed by Gallie and others and utilized by Harris, Geckeler, and Dick, up to the radical complete excision of the calcaneus, as described by Pridie. In an attempt to find a middle ground with restoration of both normal anatomy and function, a few surgeons have experimented with open reductions.

In 1946, Whittaker read two papers describing an open procedure with metal fixation in three patients. Then in 1948 Palmer, of Sweden, wrote his excellent article describing the use of a block-wedging bone graft to hold the depressed articular fragment elevated into normal position. Palmer gave credit to Lenormant and Wilmoth as having described a similar procedure in the French literature in 1932. Since then, Bremner and Warrick and Stulz, Folschweiller, and Badina have endorsed this method.

This paper is a review of experiences with twenty consecutive cases treated by Palmer's method. Of the twenty patients, sixteen were men and four were women. An adequate follow-up was obtained on nineteen patients, fifteen men and four women, whose ages ranged from twenty-five to fifty-seven years. Twelve of the fifteen men were covered by compensation insurance. One patient had sustained bilateral heel fracture, and two others had multiple injuries. In every instance, the cause was a fall from a height, the distance varying from chair height to eighty feet, in a fall from an oil derrick. All fractures in this series were comminuted and showed definite displacement of the articular surfaces of the bone. The exact deformity found at operation was variable and was sometimes difficult to describe.

PATHOLOGY

Palmer described the most common varieties of fracture, and, more recently, Warrick and Bremner have given further excellent illustrations of the variations which can occur. Essentially, the deforming factors in these fractures have been the impaction and the depression of all or a part of the central portion bearing the articular process. In the most common type of fracture, there was depression, impaction, and forward rotation of the lateral portion of the main posterior facet. This facet may also be rotated either laterally or medially. The entire intact facet has been depressed in some fractures, and in three cases in this series, the medial portion of the facet, rather than the lateral portion, was depressed. In only one patient in this series had the facet broken into more than two major fragments. In several, a small thin rim was found separated on the extreme lateral edge of the depressed section; this was simply removed and discarded.

OPERATIVE TECHNIQUE

The operative technique used is essentially that of Palmer. The patient is put in the prone position and a curved incision is made following the course of the peroneal tendons. The terminal branch of the sural nerve is protected from injury. The sheath of the peroneal

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1954.

TABLE I

EXCELLENT RESULTS

Six Cases (31.5 per cent.)

Patient	Length of Follow-up (*Months*)	Occupation	Period before Return to Work (*Months*)	
			Light Work	Heavy Work
J. B. *	22	Roofer	3.75	8
J. N. *	44	Plant maintenance man	4	4.5
B. W. *	15	Rig-builder		4
F. H.	10.5	Derrick man		3
J. F. *	33	Telephone-board repairman	.5	
F. B.	27	Housewife		

* Denotes compensation case.

tendons is divided longitudinally, and the tendons themselves are displaced anteriorly beyond the fibula. The calcaneofibular ligament is severed and the talocalcaneal joint is opened. The use of a Kirschner wire through the posterior portion of the calcaneus not only facilitates reduction of the fracture but also helps in opening up the joint space for inspection. The articular surface or surfaces are identified and the depressed portion is elevated into normal position. Once the fragment has been elevated, the multiple inferior fragments along the base of the bone which have spread laterally can be rather easily compressed with the hand into relatively normal position. This manoeuvre partially obliterates the cavity produced by the elevation of the depressed fragment, but a large gap still remains. Extra bone is then packed and wedged into this space until the elevated fragment is held well in its normal position up against the articular surface of the talus.

Gosset, of France, has described a method of elevating this fragment, with an instrument similar to a Steinmann pin, through a puncture wound only, and then incorporating the instrument into the plaster cast in order to maintain the position. This would seem to be much more difficult and uncertain than the use of extra bone. In fourteen of our patients, iliac bone was used, but in the last five of the series, zephiran-preserved bone from our bone bank was utilized. No difference could be detected in the end results in the patients with iliac-bone autografts and those with bone-bank bone grafts. In one patient, we were unable to obtain stability of the elevated fragment by the bone-graft wedging alone, because the two halves of the articular facet tended to separate. A bone peg from the bank was mortised, transversely, into a drill hole through the two fragments, and the desired stability was obtained.

The operation is done with the use of a tourniquet, which, according to our present technique, is not removed until after wound closure and cast application. We have routinely used a plaster boot for eight weeks, a walking boot for the next two weeks, and then unrestricted weight-bearing.

POSTOPERATIVE COURSE

The postoperative course of all patients was similar and was characterized by an amazing lack of reaction and swelling, and a minimal amount of pain. These factors were emphasized in Palmer's original article and were outstanding in this series. Casts did not

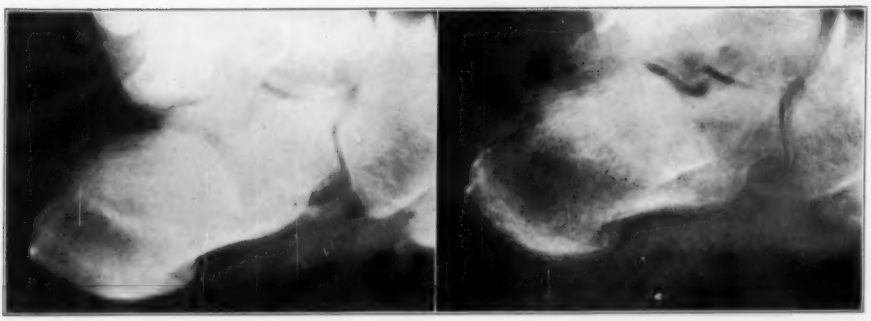

FIG. 1-A FIG. 1-B

J. F., a telephone-board repairman, thirty-six years old.
Fig. 1-A: Roentgenogram made at the time of injury.
Fig. 1-B: Roentgenogram made four months postoperatively.

have to be split, and any swelling existing before surgery subsided very rapidly. Twelve patients (60 per cent.) left the Hospital in five days or less. The average length of stay in the Hospital was 6.5 days, and, if the three patients with multiple injuries are eliminated, the average hospital stay was five days.

There were no major complications in this series. Four patients had minor complications, as follows: Two had delayed wound healing due to a small amount of slough along the suture line; one had a persistent vascular oedema necessitating the use of an elastic stocking after the removal of the cast; and one patient had a persistent hyperaesthesia on the lateral side of the foot, apparently from disturbance of the cutaneous branches of the lateral plantar nerve encountered at the operative site.

END RESULTS

Final follow-up examinations have been made during the past year. The period of follow-up varied from four and one-half months to forty-four months, and averaged 21.7 months in nineteen cases. In the follow-up, we were primarily interested in the functional result. Did the patient himself feel that his activities were in any way limited by the condition of his foot? Notes were made on the appearance of the foot and the amount of talocalcaneal joint motion. Axial and lateral roentgenograms of the heel were made.

The end results in six cases (31.5 per cent.) were judged as excellent, as shown in Table I. These six patients denied any restriction of activities, denied all pain, and said that they could perform any activity that they wished. There were five men and one woman in the group, and four of the men were covered by Workmen's Compensation Insurance. The time of return to work is indicated in the tables. No attempt has been made to judge when a housewife goes back to work, and the women have been eliminated from the "back-to-work" statistics in all of the tables. As illustrations of this group, the following brief case reports are presented:

J. B., a roofer, twenty-five years old, fell from a height. The original roentgenogram showed clearly the rotated posterior facet. The Palmer reduction operation was done, and the postoperative roentgenograms showed restoration of the normal joint surface and the iliac-bone graft beneath the articular process. This man returned to ground work with his company in less than four months and returned to roof work in eight months. Twenty-two months after his injury, while working on a very steep, high church roof, his safety equipment gave way and he fell again, — this time to his death. The patient had not lost a day's work since he had returned and had had no complaints referable to his foot when last seen, shortly before his fatal fall.

J. F., a telephone-board repairman, thirty-six years old, sustained a fracture of the calcaneus. Note the markedly depressed and rotated articular facet shown in Figure 1-A. The second roentgenogram showed a good anatomical restoration (Fig. 1-B). This man's regular work was not heavy, and he returned to work in his cast two weeks after injury. When interviewed in a thirty-three month follow-up examination, he stated

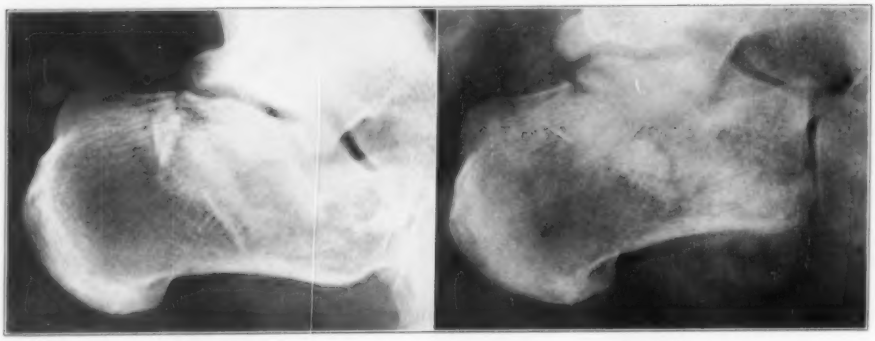

FIG. 2-A FIG. 2-B

F. H., a derrick man, forty-two years old.
Fig. 2-A: Roentgenogram showing the fracture of the calcaneus before treatment.
Fig. 2-B: Postoperative roentgenogram.

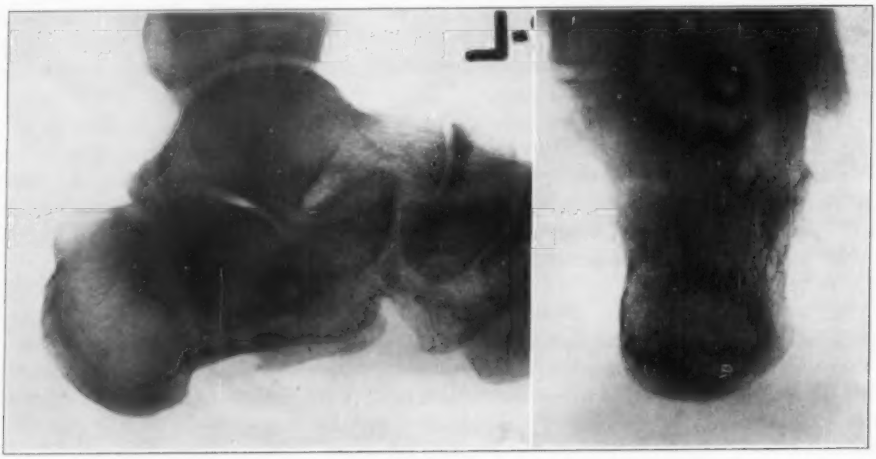

FIG. 2-C

Roentgenograms made eleven months postoperatively showing the end result after union of bone had become established.

that he had not lost a day's work; he had no complaint with regard to his foot and had no limitations, whatever, in his activities. He had about 50 per cent. of normal talocalcaneal joint motion and a normal-appearing foot except for slight thickening anterior to the operative scar.

It should be noted that few, if any, of these feet had completely normal talocalcaneal joint motion, so that it could not be said that they were anatomically perfect.

F. H., forty-two years old, was working as a derrick man on an oil rig when he sustained his injury (Fig. 2-A). At operation, two longitudinal splits were found in the articular surface of the calcaneus. A small lateral slip was removed. The two main fragments were fitted together and elevated; bank bone was used to hold them in position. The patient has less than 50 per cent. of normal talocalcaneal joint motion, but forced motion is not painful. This man returned to work just a few days after his cast had been removed and has worked up in the derrick of an oil rig every day since then. He emphatically denies any pain or restriction of activities.

B. W., a rig-builder, thirty-eight years old, fell eighty feet out of a derrick. The initial roentgenograms showed marked flattening and comminution of the calcaneus. A fifteen-month follow-up roentgenogram showed good restitution of the articular surface and of the tuber angle, but displacement of the anterior fragments has persisted. The patient has approximately 80 per cent. of normal talocalcaneal joint motion and

TABLE II

VERY GOOD RESULTS

Seven Cases (36.8 per cent.)

Patient	Length of Follow-up (*Months*)	Occupation	Period before Return to Work (*Months*)	
			Light Work	Heavy Work
V. W.	18	Trucker	3	4
S. Mc. *	7	Painter		5
R. K.	9	Internal Revenue Agent	2	
W. H. *	40	Maintenance engineer	4	
R. G. *	34	Painter		4
M. B.	21	Housewife		
J. C.	40	Housewife		

* Denotes compensation case.

has no complaints of any kind. He returned to the difficult and precarious structural steel construction work of rig-building four months after injury and plays baseball in his free time. He has mild persistant thickening of the heel.

These cases show the variations in the group classified as having an excellent functional result, indicating that there has been no significant impairment in the function of the feet for walking, working, or running.

The end results in another seven cases were judged to be very good from the functional standpoint (Table II). These patients did not complain of any serious interference with their activities, but they did have some minor complaints. Five men, including three compensation cases, and two women comprise this group, with an average follow-up of over twenty-four months. In all of these cases, there was an early return to regular work. Brief case histories of representatives of this group are as follows:

R. K., an Internal Revenue Agent, was seen eighteen days after injury. The degree of compression of the main part of the posterior facet can be judged by comparison of its level with that of the remaining medial

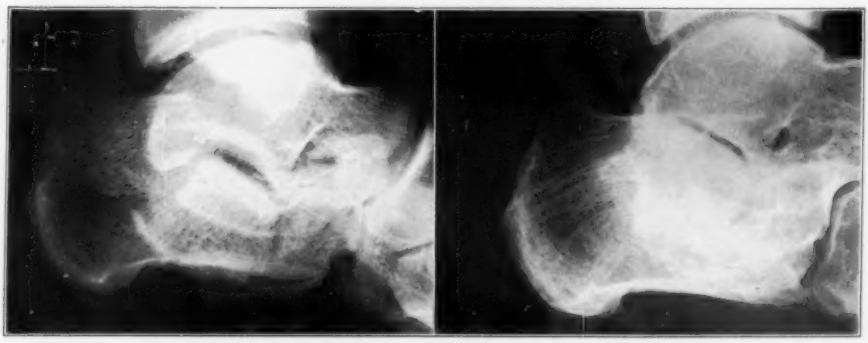

FIG. 3-A FIG. 3-B

R. K., Internal Revenue Agent, forty-two years old.

Fig. 3-A: Preoperative roentgenogram made eighteen days after injury.

Fig. 3-B: Roentgenogram made nine months postoperatively.

TABLE III

FAIR RESULTS

Five Cases (26.3 per cent.)

Patient	Length of Follow-up (*Months*)	Occupation	Period before Return to Work (*Months*)	
			Light Work	Heavy Work
E. M. *	24	Shop foreman	1	10
H. B. *	10	Roughneck		2.25
G. D. *	35	Rig-builder (bilateral fractures)	11	30
J. M. *	7	Laborer	4†	
R. K.	4.5	Housewife		

* Denotes compensation case.

† Later this man was able to return to his regular heavy work.

portion (Fig. 3-A). The operative note states that this fragment was elevated one inch and that considerable bank bone was necessary to fill the defect. A roentgenogram made at nine months (Fig. 3-B) showed some traumatic arthritis, although the patient said that he could think of no activity in which he was restricted. He did state that he had some discomfort on going downstairs and some aching after extensive walking. He has only mild thickening beneath the lateral malleolus and about 50 per cent. of normal talocalcaneal joint motion.

S. Mc., forty-eight years old, was a painter. Figure 4-A shows a severe degree of central depression of the calcaneus, and Figure 4-B shows the reduced fracture, probably one of the better anatomical restorations in the series. The length of follow-up is seven months. Although he has no difficulties in carrying on his trade as a painter, he does complain of minor discomfort when walking on rough surfaces.

The excellent and very good results make up almost 70 per cent. of the entire series, and the authors feel that these patients treated by this method have better function than has been obtained in similar patients treated by closed methods.

The results classified as fair are shown in Table III. These five patients represent 26.3 per cent. of the group followed, and all have some restriction of activities because

FIG. 4-A FIG. 4-B

S. Mc., painter, forty-eight years old.

Fig. 4-A: Roentgenogram showing the fracture.

Fig. 4-B: Roentgenogram made seven months postoperatively.

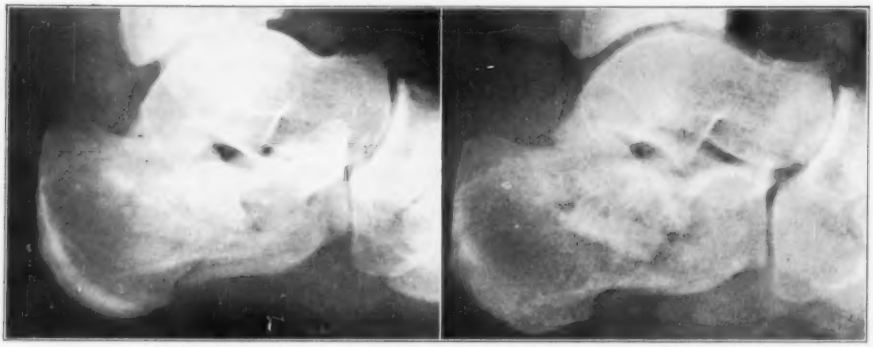

FIG. 5-A FIG. 5-B

A. S., patient classified as having a poor result.

Fig. 5-A: Preoperative roentgenogram made twenty-one days after injury.

Fig. 5-B: Roentgenogram made about one year after original injury, showing incongruous articular surfaces.

of pain. Brief notes taken from the end results in the case histories of three of these patients are as follows:

E. M., shop foreman. The patient is able to stand and walk all day without pain and complains only that dancing makes his calf sore and causes his ankle to ache. His foot is distorted, however, and we feel certain that this man could not climb or run well; he had not been able to do all of his regular duties for ten months.

H. B., roughneck. Although the patient returned to the oil field as a roughneck, wearing a walking cast, nine weeks after injury and thereafter never lost a day's work, he continued to complain of daily pain, and the end result could not be called good.

G. D., rig-builder. Roentgenograms of the bilateral fracture of the calcaneus of this patient showed a poor result in one foot, and it was two and one-half years before he could return to his regular work; in the interim he had worked as a carpenter. At thirty-five months, he was well pleased with his feet and said that he was without pain. One foot remains distorted, however, and the follow-up roentgenograms showed a poor anatomical restoration.

One patient has been classified as having a poor result.

A. S., refinery worker. Although the patient returned to light work in three and one-half months and worked regularly, he continued to complain of pain throughout the year, and arthrodesis was advised. The explanation can be seen in the roentgenogram (Fig. 5-B); the rotated fragment of the facet had not been adequately derotated, with the result that the two articular surfaces are not exactly apposed. (This was the second patient operated upon in the series, and the result in this case probably represents a technical error.)

COMPARISON WITH OTHER SERIES

It is of interest to compare this series of open reductions with the twenty-seven cases of arthrodesis reported by Geckeler. He reported 70 per cent. good results and 30 per cent. fair. An important difference, however, is that Geckeler describes a fair result as indicating "ability to walk with some discomfort but inability to return to regular work". In our series, every patient returned to work. The average time before the return to work of our fifteen male patients was 3.64 months, as compared to 6.1 months for Geckeler's patients treated by arthrodesis, of whom 30 per cent. were not working at all.

SUMMARY

Experiences with twenty open reductions for fractures of the calcaneus are reported, with follow-up studies on nineteen patients, averaging 21.7 months. Excellent or very good functional results were achieved in 68.4 per cent. of these patients. The low incidence of morbidity following surgery, the short hospitalization periods, and the early return to work were important features. The degree of excellence of the anatomical restoration of the entire contour of the calcaneus did not necessarily parallel the degree of excellence of

the functional result. The study suggests that restoration of a smooth weight-bearing articular surface is the main feature leading to a good end result. The authors feel that the Palmer method of treatment is far superior to other methods they have used, and they will continue to use it as standard treatment for fractures of the calcaneus requiring open reduction.

REFERENCES

1. Belenger, M.; Vander Elst, E.; et Lorthioir, J., Fils: Les fractures du calcanéum; leur traitement et le traitement des séquelles. Acta Orthop. Belgica, **17:** 61, 1951. (Abstract in Surg., Gynec., and Obstet., Internat. Abst. Surg., **93:** 494, 1951.)
2. Bremner, A. E., et Warrick, C. K.: Les fractures du calcanéum. Acta Orthop. Belgica, **17:** 217, 1951. (Abstract in Surg., Gynec., and Obstet., Internat. Abst. Surg., **94:** 392, 1952.)
3. Carothers, R. G., and Lyons, J. F.: Early Mobilization in Treatment of Os Calcis Fractures. Am. J. Surg., **83:** 279–280, 1952.
4. Dick, I. L.: Primary Fusion of the Posterior Subtalar Joint in the Treatment of Fractures of the Calcaneum. J. Bone and Joint Surg., **35-B:** 375–380, Aug. 1953.
5. Gallie, W. E.: Subastragalar Arthrodesis in Fractures of the Os Calcis. J. Bone and Joint Surg., **25:** 731–736, Oct. 1943.
6. Geckeler, E. O.: Comminuted Fractures of the Os Calcis. Choice of Treatment. Arch. Surg., **61:** 469–476, 1950.
7. Gosset, J.: Le traitement des fractures du calcanéum avec enfoncement thalamique. Technique personelle. Sem. Hôp. Paris, **26:** 4491, 1950.
8. Harris, R. I.: Fractures of the Os Calcis. Their Treatment by Tri-Radiate Traction and Subastragalar Fusion. Ann. Surg., **124:** 1082–1100, 1946.
9. Lenormant, Ch., et Wilmoth, P.: Les fractures sous-thalamiques du calcanéum. Leur traitement par la réduction à ciel ouvert et la greffe ostéo-périostique. J. Chir., **40:** 1–25, 1932.
10. Palmer, Ivar: The Mechanism and Treatment of Fractures of the Calcaneus. Open Reduction with the Use of Cancellous Grafts. J. Bone and Joint Surg., **30-A:** 2–8, Jan. 1948.
11. Pridie, K. H.: A New Method of Treatment for Severe Fractures of the Os Calcis. A Preliminary Report. Surg., Gynec., and Obstet., **82:** 671–675, 1946.
12. Stulz, E.; Folschweiller, J.; et Badina, J. J.: Réflexions sur le traitement des fractures du calcanéum d'après 61 observations. Acta Orthop. Belgica, **17:** 231, 1951. (Abstract in Surg., Gynec., and Obstet., Internat. Abst. Surg., **94:** 392, 1952.)
13. Warrick, C. K., and Bremner, A. E.: Fractures of the Calcaneum. With an Atlas Illustrating the Various Types of Fracture. J. Bone and Joint Surg., **35-B:** 33–45, Feb. 1953.
14. Whittaker, A. H.: Fractures of the Os Calcis. Preliminary Report. Am. J. Surg., **74:** 378–379, 1947.
15. Whittaker, A. H.: Treatment of Fractures of the Os Calcis by Open Reduction and Internal Fixation. Am. J. Surg., **74:** 687–696, 1947.

DISCUSSION

Dr. Louis H. Edmunds, Seattle, Washington: When the report of Dr. Palmer's new approach to this problem was first published, it was enthusiastically received. However, not every surgeon has been able to duplicate the good results reported by him or by Dr. Maxfield. They may have been able to obtain a foot that looked good in roentgenograms, but the clinical result often has been a stiff, "frozen" foot, with pain on weight-bearing; many surgeons were then quick to discard the method. Others, like Dr. Maxfield and ourselves, have continued its use, trying to correct its deficiencies and to see why it has failed in some instances.

We feel that a good anatomical reduction can be accomplished by Palmer's method in properly selected cases. It seems axiomatic that the better the anatomical reduction, the better the functional results will be. If this is true, why has the method not been widely successful?

There are several possible reasons for the failures:

1. The fracture may be so badly comminuted that it is technically impossible to obtain a satisfactory reduction. One of Dr. Maxfield's cases seems to illustrate this point.

2. The plantar surface of the calcaneus may be so fragmented that it will not support the bone graft which, in turn, is to support the articular surface. It is like trying to put up a tent pole to support a tent in ground that gives way. Furthermore, it may produce a painful protrusion on the sole of the foot. Two of our patients had this, and one had to have the protrusion removed surgically.

3. The bone graft may be driven in so far medially that it spreads the longitudinal split between the intact medial fragment and the depressed lateral fragment. Apparently this happened in one of Dr. Maxfield's cases; he corrected this by a horizontally placed bone peg.

(Continued on page 155)

THE DIFFUSION OF ANTIBIOTICS THROUGH THE SYNOVIAL MEMBRANE*

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The use of antibiotics in infectious arthritis is now generally accepted and good results have been reported. Key[11], in 1951, emphasized their role in the management of acute hematogenous osteomyelitis and of pyogenic arthritis. Steindler stated that the use of antibiotics in joint infection has "removed the condition from the group of dire emergency" and has made it possible for the surgeon to choose the optimum time for surgery. However, he cautioned against relying solely on antibiotics and he advocated early drainage before any destruction of the cartilage takes place. He reported cases in which joint destruction had occurred because of delayed drainage, even though antibiotics and other general measures had brought the condition under control.

McAdam and his associates, in 1945, stated that normal synovial membrane is relatively impermeable to penicillin, although there is some evidence that it can reach the joint at an adequate bacteriostatic level in traumatic synovitis and in infective arthritis. Studies on the diffusion of penicillin into the joint fluid following its intramuscular administration were reported by Balboni and his coworkers in the same year. Hirsh and his associates studied the reabsorption of the drug following its intra-articular instillation. Shwachman and his associates claimed that "aureomycin, unlike penicillin and streptomycin, is distributed rather uniformly throughout the body rather than being confined almost exclusively to extracellular fluid". Smillie advised local therapy in addition to the systemic use of antibiotics. He summarized his findings by stating that "the antibiotics are ancillary, not an alternative to good surgery".

The question now arises as to which of the different antibiotics are able to penetrate through the synovial membrane into the joint cavity and in what quantities. Little is known about the mechanism of the passage of any material from the blood stream into the synovial fluid. If dye is injected intravenously, it will stain the synovial fluid. In pathological joint conditions with effusion, the sugar content of the fluid varies with the blood-sugar level. The Wassermann reaction of the fluid also corresponds to that of the blood. It appears that some of the substances in the blood can easily reach the joint cavity and that the synovial fluid is in close osmotic relationship with the blood.

The origin of synovial fluid has not been definitely determined. Normal synovial fluid is neither a transudate nor an exudate. It is not a secretion, since there are no secretory glands in the synovial membrane. To gain a better understanding of how the synovial membrane is formed and why some substances can pass through it while others do not, it is necessary to review the histology and the physiology of the synovial membrane as described by Key[10].

It was formerly believed that the synovial membrane was lined by a layer of epithelium, but the work of His on the primary germ layer disproved this. It was then held that the synovial membrane is lined by a mesothelial layer similar to the peritoneum, pericardium, and the pleura. However, Hueter, in 1866, showed that the joint cavities are not lined by a continuous layer of endothelial cells but rather by a cellular connective-tissue surface which is irregular and incomplete. While the general pattern remains the same, the character varies considerably in the different areas in the same joint, in different joints, and in the corresponding joints of different animals. He believed that the variation in the character of the membrane was an adaptation to different mechanical conditions and to the difference in the stress and strain to which a particular area is subjected. However, this

* Read at the Meeting of the New Jersey Orthopaedic Society, Atlantic City, New Jersey, April 18, 1953.

view was not shared by Smillie, who believed that external mechanical factors alone cannot be responsible for the variability in structure. He believed that the polymorphism of the synovial lining is a specific property and that the formation of mucin is a physiological function of the synovial cells. Key[10] described three types of synovial membrane, all of which may be found in the same joint.

1. *The areolar type* constitutes the greater part of the synovial membrane. It is found wherever the membrane is not subjected to pressure or strain and where function of the joint requires movement of the surface of the membrane on the underlying tissue. The surface layer is a thin sheet of collagenous fibrous tissue in which are embedded the synovial cells, either partly or entirely beneath the surface; the thickness varies from a single layer to four layers. In disease, the membrane becomes thickened.

2. *The fibrous type* covers the interarticular ligaments and tendons and is found in those areas which are subjected to more strain. It is less cellular, being composed mostly of dense collagenous fibers with some elastic fibers, and is closely adherent to the underlying structures.

3. *The adipose type* covers the fat pads. The structure is similar to that of the areolar type, except that it rests directly on the fat tissue rather than on the loose subsynovial areolar tissue.

The synovial cells vary in shape, depending on their location. They contain no secretory granules, Golgi apparatus, or cannaliculi. In both fresh and stained preparations, some cells show clear vacuoles, the contents of which do not stain in either the fixed or the supravital-staining preparations. It is possible that these vacuoles contain mucin which is released into the joint fluid. Some of the cells contain tiny fat granules.

The synovial membrane as a whole is richly supplied with blood vessels, the fibrous type having less than the other types. The blood vessels penetrate all but the smallest villi, the larger ones being extremely rich in blood supply.

The lymphatic system is less well understood. Fluid forced out from the joint cavity, either by pressure or through the pumping action of joint motion, does not enter into definite lymphatic vessels but rather into tissue spaces. Tillmanns, in 1876, injected the lymphatic vessels of horses and cattle and described a double network of lymphatic vessels in the synovial membrane. This network consisted, according to his studies, of a superficial and a deep layer anastomosing with each other by means of fine lymph capillaries. However, this description has been rejected by other workers. It is also an open question whether the joint cavity is connected with the lymphatics by means of stomata. Synovial fluid, crystalloids, and fine colloids pass from the joint cavity into the blood stream. If dye is injected into the joint cavity, most of it is apparently absorbed into the blood stream and a lesser amount into the lymphatics, since the regional lymph nodes are only slightly stained. Larger particles are removed by phagocytic action.

Guerra, in 1946, stated that the ground substance in the synovial membrane and in the synovial fluid consists entirely of hyaluronic acid and of chondroitin sulphuric acid which, when hydrolyzed, produces a decrease in the viscosity of the synovial fluid and an increase in the permeability of the synovial membrane. Ragan and Meyer stated that hyaluronic acid is synthesized by polymerization of polysaccharides; it is produced by the connective tissue from a disaccharide precursor formed in the liver. In certain diseases there is a failure on the part of the connective tissue to complete the synthesis of the higher polysaccharides, resulting in pooling of a low polymer hyaluronate which contributes to the formation of granulation tissue. Robertson and his associates isolated a bacterial enzyme which hydrolyzes synovial mucin, causing a decrease in the viscosity of the fluid. They called it "mucinase". Seifter and his coworkers studied the permeability of the synovial membrane by instilling phenolsulphonphthalein into the joint space and then measuring the speed of absorption and excretion of the dye into the urine. They found a marked increase in permeability of the membrane when either hyaluronidase or desoxycorticosterone

TABLE I

RESULTS FOLLOWING INTRAMUSCULAR INJECTION OF POTASSIUM PENICILLIN G

Age of Patient (*Years*)	Pathological Condition	Dosage (*Units*)	Drug Level in Fluid (*Units per Cubic Centimeter*)
50	Chronic synovitis	500,000	0.5
76	Chronic synovitis	500,000	2.0
67	Traumatic effusion	500,000	2.0
82	Traumatic effusion	300,000	0.4
33	Congestive effusion	300,000	0.128

acetate was instilled into the joint together with the dye; the effect in either case was maximal and could not be augmented by the other. On the other hand, if adrenal cortical extract was used instead, there was a decrease in permeability; thus they concluded that the permeability of the synovial membrane is in part controlled by hormonal balance.

From the foregoing it appears that the synovial membrane is a semipermeable membrane through which water and fine molecules in solution can pass freely from the blood stream into the joint cavity and vice versa. The viscosity of this fluid is increased by hyaluronic acid synthesized by connective tissue and by the mucin produced by the synovial cells. Since the viscosity of the fluid and the permeability of the synovial membrane vary with the amount of hyaluronic acid present, any condition which will alter its concentration, either by a decrease in the rate of synthesis or by an increase of autolysis, will change the physiology of the membrane. The disturbance in physiology may make the allowance for the passage of larger molecules through the membrane. A shift in the hormonal equilibrium resulting in a relative increase of the desoxycorticosterone acetate will give the same effect.

The present investigation was undertaken to determine which of a number of antibiotics pass into the synovial fluid; the purpose of this work being to establish a rational therapy in pyogenic arthritis. Since no fluid was obtainable from normal joints, studies on such could not be performed. The synovial fluid used for this study was obtained from cases of genicular hydrarthrosis of an inflammatory or traumatic nature. Unfortunately, cases of pyogenic arthritis, for which the use of antibiotics is intended, were not available. Synovial-fluid analyses were performed at the Jersey City Medical Center, Department of Laboratories. Biological assay, by use of a young culture of a highly susceptible microorganism, was the analytical method employed. Serial dilution was used to determine concentration of the drug whenever there was any evidence of antibiotic activity by the specimen of synovial fluid. The dosage for each drug, the route of administration, the time interval between drug administration and aspiration of the specimen from the knee, and the results of analysis of the synovial fluid follow.

Potassium Penicillin G

Aqueous solution of potassium penicillin G in different doses was administered in five cases of genicular hydrarthrosis. Three hours later, the synovial fluid was aspirated and tested for the presence of the drug. The first three patients were given a single dose of 500,000 units, while the last two were given 300,000 units. Results showed a drug level in the fluid approximately proportional to the dosage administered. However, of the three patients given a dose of 500,000 units, there was a variation in the drug level from 0.5 to 2.0 units per cubic centimeter of fluid. This range of variation is too great to be explained by a difference in the level of the drug in the blood alone. It would seem that there must be a difference in the permeability of the synovial membrane in different subjects which permits the passage of greater quantities of the drug in some and of smaller quantities in others.

TABLE II

RESULTS FOLLOWING INTRAMUSCULAR INJECTION OF PROCAINE PENICILLIN G *

Age of Patient (*Years*)	Pathological Condition	No. of Days	Drug Level in Fluid (*Units per Cubic Centimeter*)
24	Traumatic effusion	3	None
67	Traumatic effusion	10	None
67	Traumatic effusion	15	None
66	Chronic synovitis	20	None
18 **	Traumatic effusion	20	0.5

* All patients received 300,000 units twice daily for the number of days indicated.
** The patient had received 100,000 units of potassium penicillin G every three hours for two days previous to therapy with procaine penicillin G.

Procaine Penicillin G

Five cases were studied; the patients had been receiving 300,000 units of procaine penicillin G twice daily for a period varying from three to twenty days.

The first specimen was obtained from the knee joint of a patient who had been receiving intramuscular injections of 300,000 units of procaine penicillin G twice daily for ten days. Surprisingly, there was no evidence of penicillin in the fluid. Thus, more cases were studied to determine whether the foregoing result might not be due to some technical error. In all cases except one, the results were negative for the presence of penicillin in the fluid.

Streptomycin Sulphate

Four cases of hydrarthrosis of the knee were studied for the presence of streptomycin in the synovial fluid following the administration of the drug. Half of the total dose was given in the evening and the other half the next morning. Three hours later the fluid was aspirated and tested.

The first patient studied was given one gram of streptomycin twice, with a twelve-hour interval. Three hours after the last dose, the knee was aspirated; analysis showed a drug level of twelve micrograms per cubic centimeter of fluid. Since such a large dose is seldom used clinically, the usual therapeutic dose of 0.5 gram was given instead to the next three patients. The results showed no evidence of streptomycin in the synovial fluid. The single positive case may have been due either to the large dose given or to an increased permeability of the synovial membrane, or to both conditions.

Aureomycin Hydrochloride

Six patients were given 250 milligrams of aureomycin hydrochloride by mouth every four hours for four doses, that is, a total dose of one gram. This dose is considered to be adequate to maintain a therapeutic blood level; increasing the dose does not produce a proportionate elevation of the concentration in the blood, as there are certain factors

TABLE III

RESULTS FOLLOWING INTRAMUSCULAR ADMINISTRATION OF STREPTOMYCIN SULPHATE

Age of Patient (*Years*)	Pathological Condition	Dosage (*Grams*)	Drug Level in Fluid (*Micrograms per Cubic Centimeter*)
78	Traumatic effusion	2	12
45	Traumatic effusion	1	None
33	Congestive effusion	1	None
32	Chronic synovitis	1	None

TABLE IV

RESULTS FOLLOWING ORAL ADMINISTRATION OF AUREOMYCIN HYDROCHLORIDE

Age of Patient (*Years*)	Pathological Condition	Dosage (*Grams*)	Drug Level in Fluid (*Micrograms per Cubic Centimeter*)
38	Traumatic effusion	1	10 to 12
18	Chronic synovitis	1	Trace
30	Traumatic effusion	1	None
17	Traumatic effusion	1	None
50	Chronic synovitis	1	None
16	Traumatic effusion	1	None

which limit the ability of the intestinal mucosa to absorb more of the drug. The fluid was obtained four hours after the last dose. The results of the test are shown in Table IV.

Four specimens showed no evidence of the drug; one had a trace, the amount being insufficient to determine the concentration; another showed a level of ten to twelve micrograms of aureomycin hydrochloride per cubic centimeter of fluid. The positive result was in a man, thirty-eight years old, who had twisted his knee one week before the test. The fluid obtained was frankly bloody, but there was no evidence of actual bleeding. The specimen showing a trace of the drug was obtained from a patient who had recurrent effusion of the knee with no history of recent acute trauma.

TABLE V

RESULTS FOLLOWING ORAL ADMINISTRATION OF TERRAMYCIN HYDROCHLORIDE

Age of Patient (*Years*)	Pathological Condition	Dosage (*Grams*)	Drug Level in Fluid
51	Chronic arthritis	1.0	Trace
31	Traumatic effusion	1.0	Trace
29	Chronic arthritis	3.5	Trace
68	Traumatic effusion	2.0	None

Terramycin Hydrochloride

The procedure followed was similar to that used for aureomycin hydrochloride. Four cases were studied; three showed traces of the drug in the synovial fluid, while the fourth case was negative.

Chloramphenicol

The experimental procedure was the same as in the two foregoing drugs. Four cases were studied; two specimens were negative, while two showed a trace of the drug in the fluid.

TABLE VI

RESULTS FOLLOWING ORAL ADMINISTRATION OF CHLORAMPHENICOL

Age of Patient (*Years*)	Pathological Condition	Dosage (*Grams*)	Drug Level in Fluid
56	Traumatic effusion	1.0	None
45	Traumatic effusion	2.0	None
67	Traumatic effusion	2.0	Trace
58	Traumatic effusion	1.5	Trace

DISCUSSION

Of the different antibiotics studied, only potassium penicillin G was consistently found in the synovial fluid in appreciable amounts. Biological assay provided no way to determine whether the other drugs were able to pass through the synovial membrane in an inactivated form. This makes little practical difference, however, since the drug would have no therapeutic value in that case. In a few cases, the other drugs were found in the fluid in varying amounts, suggesting that there may be some individual differences in the permeability of the synovial membrane. These facts, together with the indiscriminate choice of antibiotics, may explain the conflicting results obtained in the treatment of pyogenic arthritis, so that early and adequate drainage becomes necessary.

Since the dosage of procaine penicillin G used in the experiment is considered to be adequate to maintain an almost constant blood level, the absence of penicillin in the fluid can be attributed only to its failure to pass through the barrier of the synovial membrane. The single patient with a positive result had a surgical procedure performed on his knee three weeks previously and had received 100,000 units of aqueous solution of potassium penicillin G every three hours for two days, followed by 300,000 units of procaine penicillin G twice daily for the next twenty days. This raises the question whether the drug in the fluid was the residuum from the potassium penicillin G previously given or from the procaine penicillin G given later. If the residuum was from the potassium penicillin G, the question arises as to how long the drug remains in the synovial fluid after its administration. Balboni and his associates studied the level of penicillin in the serum and in the synovial fluid at different intervals following an intramuscular administration of from 25,000 to 40,000 units. They found that the maximum level in the fluid persists longer than in the serum, but that the drug did not tend to accumulate in the joint fluid. Hirsh and his associates found that, when the drug was given parenterally, it could be detected in some cases in the synovial fluid as early as fifteen minutes after injection and that its concentration in the fluid was up to 50 per cent. greater than in the serum. The diffusion of the drug into the joint fluid was not significantly altered by the body temperature, for in only two of six patients was there a slight increase in the amount of penicillin exchanged between joint fluid and blood. They also injected from 30,000 to 200,000 units of penicillin into the joint cavities and found the drug to be present for as long as twenty-four to 120 hours. In the case under discussion, it is possible that, since the molecules of potassium penicillin G can pass freely through the synovial membrane while the procaine penicillin G molecules cannot, an osmotic equilibrium was established between the potassium penicillin G molecules in the fluid and the procaine penicillin G molecules in the blood.

In tuberculosis of the joints, good results with the use of streptomycin alone or in conjunction with para-aminosalicylic acid have been reported. Of twenty-one cases of tuberculosis involving the freely movable peripheral joints, DeRoy and Fisher reported good painless motion in eleven treated by adequate drainage coupled with streptomycin therapy; there was no reactivation of infection. Harris and associates were impressed by the good results obtained in two tuberculous hips and one case of tuberculous synovitis of the knee complicated by miliary tuberculosis of the lung treated by streptomycin and para-aminosalicylic acid. They concluded that early treatment with adequate doses of these two drugs for a prolonged period offers real hope of cure in tuberculosis of bones and joints. However, Smith, in discussing the report of the Public Health Service Cooperative Investigation on the evaluation of streptomycin therapy, cited three cases of synovial tuberculosis of the knee which were treated by complete synovectomy combined with the use of streptomycin. The results were absolute failure in two cases, while in the third case the disease appeared to be brought under control, at least temporarily. Regarding the use of chemotherapy in bone and joint tuberculosis, Ghormley stated that "The hope that, with early diagnosis and early treatment by means of streptomycin, joints could be salvaged and extensive destruction prevented has not been realized".

TABLE VII

MOLECULAR WEIGHTS OF THE ANTIBIOTICS USED IN THIS STUDY

Antibiotic	Molecular Weight
Chloramphenicol	323.14
Potassium penicillin G	372.47
Terramycin hydrochloride	455.42
Aureomycin, free base	481.00
Aureomycin hydrochloride	517.0
Procaine penicillin G	588.71
Streptomycin sulphate	1,136.00

These conflicting results may be due to the failure of the drug to reach the joint cavity in sufficient concentration. If the infection is confined to the synovial membrane only, which is richly supplied with blood vessels, streptomycin may be able to control the disease. If the infection involves the joint itself, the antibiotic will not be able to reach it, and it becomes necessary to inject the drug directly into the joint cavity to supplement its systemic use. Ahern and Arden used this method and obtained good results in eight of ten cases of synovial tuberculosis. They injected one gram of the drug into the joint cavity twice a week for ten to twenty-two doses.

Neither aureomycin nor terramycin passes freely through the synovial membrane, but both have been found to be of value in the management of pyogenic arthritis. We are therefore safe in assuming that both drugs protect the membrane from further damage and so prevent the spread of infection into the blood stream. The infection is thus confined inside the joint cavity, which, if drained early, may escape destruction. There is no available report concerning the use of chloramphenicol in pyogenic arthritis, but, since it does not diffuse freely into the synovial fluid, its effects would probably be similar to those of aureomycin and terramycin.

To explain the difference in the permeability of the synovial membrane to the various antibiotics, the results obtained in the experiment were correlated with the size of the molecules or with the molecular weight of each substance, as shown in Table VII. Since these drugs are biological products and may contain more than one substance, their molecular weights may vary, although there is an accepted chemical formula for each. Only chloramphenicol has a definite structural formula and a constant molecular weight.

From Table VII it is evident that chloramphenicol and potassium penicillin G have the smallest molecular weights. If the synovial membrane allows the passage only of substances of small molecular weights, the expectation would be that chloramphenicol would be present in the synovial fluid in all cases and in the largest concentration. However, this was not confirmed by the results of this experiment. Since the drug was given by mouth, it is possible that in its passage through the gastro-intestinal tract the molecules had been conjugated with another substance such as a protein, or that two chloramphenicol molecules united. It would be interesting to find out whether chloramphenicol would pass through the synovial membrane if given parenterally. Unfortunately, there is at present no preparation for parenteral use.

SUMMARY

Twenty-eight samples of synovial fluid were analyzed for the presence of different antibiotics following their administration as specified. Unfortunately, no determination of the drug levels in the blood was done at the same time as the synovial-fluid examination, and it is possible that in some instances adequate concentration of the drug was not present in the blood to permit its diffusion into the joint fluid. In the dosage given, which is claimed by its manufacturer to be adequate, only the aqueous solution of potassium penicillin G

was found consistently in the fluid tested, while the other drugs were present in small amounts in some cases or not at all. Since the synovial membrane is semipermeable, allowing the passage of true solutions of small molecules, both chloramphenicol and potassium penicillin G, which have the smallest molecular weights, should have been present in the fluid of all cases tested. However, it has been demonstrated that chloramphenicol did not pass freely; this may be due either to changes in its molecular structure as it passes through the gastro-intestinal tract, or to the fact that molecular weights have no effect on the diffusion of substances through the synovial membrane. The results of this study showed no difference in the permeability of the membrane in the different age groups. Neither a history of recent acute trauma nor chronic inflammation had any definite effect on the permeability of the synovial membrane.

The antibiotic of choice in the management of pyogenic arthritis is potassium penicillin G, provided the organisms are penicillin-sensitive; the other antibiotics are of value only in preventing the spread of the infection into the blood stream.

NOTE: For Table VII, the data on aureomycin were supplied by the Lederle Laboratories Division, American Cyanamid Company. Parke, Davis and Company provided the information concerning chloramphenicol, potassium penicillin G, and procaine penicillin G. The molecular weight of terramycin hydrochloride was computed from the structural formula supplied by Chas. Pfizer and Co., Inc., while that of streptomycin sulphate was computed from the accepted structural formula of *New and Nonofficial Remedies* 1951, Council on Pharmacy and Chemistry of the American Medical Association.

REFERENCES

1. AHERN, R. T., and ARDEN, G. P.: Intra-Articular Streptomycin in Tuberculosis of the Knee. British Med. J., **1**: 466–468, 1952.
2. BALBONI, V. G.; SHAPIRO, I. M.; and KYDD, D. M.: The Penetration of Penicillin into Joint Fluid Following Intramuscular Administration. Am. J. Med. Sciences, **210**: 588–591, 1945.
3. DEROY, M. S., and FISHER, HARRY: The Treatment of Tuberculous Bone Disease by Surgical Drainage Combined with Streptomycin. J. Bone and Joint Surg., **34-A**: 299–329, Apr. 1952.
4. GHORMLEY, R. K.: Chemotherapy in Bone and Joint Tuberculosis. J. Bone and Joint Surg., **34-A**: 254, Apr. 1952.
5. GUERRA, FRANCISCO: The Action of Sodium Salicylate and Sulfadiazine on Hyaluronidase. J. Pharmacol. and Exper. Therapeut., **87**: 193–197, 1946.
6. HARRIS, M. B.; COULTHARD, M. D.; and DEWAR, F. P.: Streptomycin in the Treatment of Bone and Joint Tuberculosis. J. Bone and Joint Surg., **34-A**: 279–287, Apr. 1952.
7. HIRSH, H. L.; FEFFER, H. L.; and O'NEIL, C. B.: A Study of the Diffusion of Penicillin across the Serous Membranes of Joint Cavities. J. Lab. and Clin. Med., **31**: 535–543, 1946.
8. HIS, WILHELM: Die Häute und Höhlen des Körpers. Basel, Schweighauserische Universitäts-Buchdruckerei, 1865.
9. HUETER, C.: Zur Histologie der Gelenkflächen und Gelenkkapseln, mit einem kritischen Vorwort über die Versilberungsmethode. Virchows Arch., **36**: 25–80, 1866.
10. KEY, J. A.: The Synovial Membrane of Joints and Bursae. *In* Special Cytology. The Forms and Functions of the Cell in Health and Disease, edited by E. V. Cowdry, pp. 737–756. New York, Paul B. Hoeber, 1928.
11. KEY, J. A.: The Management of Acute Hematogenous Osteomyelitis and Pyogenic Arthritis. Clin. Med., **58**: 328–331, 1951.
12. MCADAM, I. W. J.; DUGUID, J. P.; CHALLINOR, S. W.; and MCCALL, A.: Penicillin Treatment of Serous-Cavity Infections. Lancet, **2**: 843–848, 1945.
13. RAGAN, CHARLES, and MEYER, KARL: The Hyaluronic Acid of Synovial Fluid in Rheumatoid Arthritis. J. Clin. Invest., **28**: 56–59, 1949.
14. ROBERTSON, W. VAN B.; ROPES, M. W.; and BAUER, WALTER: Mucinase: A Bacterial Enzyme Which Hydrolyzes Synovial Fluid Mucin and Other Mucins. J. Biol. Chem., **133**: 261–276, 1940.
15. SEIFTER, JOSEPH; BAEDER, D. H.; and BEGANY, A. J.: The Influence of Hyaluronidase and Steroids on Permeability of Synovial Membrane. Proc. Soc. Exper. Biol. and Med., **72**: 277–282, 1949.
16. SHWACHMAN, H.; FOLEY, G. E.; and COOK, C. D.: Aureomycin in Pediatrics. A Review. J. Pediat., **38**: 91–127, 1951.
17. SMILLIE, I. S.: Injuries of the Knee Joint. Ed. 2. Baltimore, Williams and Wilkins Co., 1951.
18. SMITH, A. DEF.: Discussion of United States Public Health Service Cooperative Investigation [21].
19. STEINDLER, A.: Pyogenic Arthritis. Bull. New York Acad. Med., **27**: 101–123, 1951.
20. TILLMANNS, H.: Die Lymphgefässe der Gelenke. Arch. f. Mikr. Anat., **12**: 649–664, 1876.
21. UNITED STATES PUBLIC HEALTH SERVICE COOPERATIVE INVESTIGATION: Evaluation of Streptomycin Therapy in a Controlled Series of Ninety Cases of Skeletal Tuberculosis. J. Bone and Joint Surg., **34-A**: 288–298, Apr. 1952.

INCARCERATION OF THE FIRST SACRAL NERVE IN A LATERAL BONY RECESS OF THE SPINAL CANAL AS A CAUSE OF SCIATICA

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The purpose of this paper is to describe a bony recess in the spinal canal at the level of the fifth lumbar and first sacral vertebrae, to discuss its possible clinical significance in the causation of sciatic pain, and to relate this to the general problem of root compression in the lower lumbar region. Normally a bony recess exists at the level of the fifth lumbar and first sacral vertebrae medial to the intervertebral foramen, the posterior wall of which is formed by the superior articular process of the sacrum and the anterior wall by the fifth lumbar disc and vertebral body. In certain subjects this recess is considerably deeper, the posterior wall extending toward the mid-line. When the first sacral nerve becomes incarcerated in this recess, compression results, with consequent production of sciatic pain. So far as we are aware, the presence of a deep recess in this area and its role in the compression of the first sacral nerve have not been previously described.

ANATOMICAL CONSIDERATIONS

The arrangement of the articular processes at the level of the fifth lumbar and first sacral vertebrae is different from that found at the levels above, although at the level of the fourth and fifth lumbar vertebrae it may be somewhat similar. At the level of the fifth lumbar and the first sacral vertebrae, instead of the usual relationship found in the upper lumbar vertebrae, in which the articular processes in the sagittal plane lie almost parallel to each other on both sides, considerable variation is found. The arrangement of the articulation of the fifth lumbar and the first sacral vertebrae is rather curved, the anterior portion lying at or nearly in the frontal plane and the lateral portion lying in the sagittal plane. In many cases the arrangement varies on the two sides, the joint lying mainly in the frontal plane on the one side and mainly in the sagittal plane on the other. This was well illustrated by Badgley and by Horwitz and Smith. In a number of cases both joints may lie almost entirely in the frontal plane. The portion of the articular process of the sacrum which lies in the frontal plane extends a variable distance toward the mid-line and forms the posterior wall of a recess, the anterior wall of which is the fifth lumbar disc and the body of the fifth lumbar vertebra (Fig. 1). The width, height, and depth of this bony recess vary considerably. There has been speculation as to the relationship between the arrangement of the articular processes at the level of the fifth lumbar and the first sacral vertebrae and instability of the fifth lumbar vertebra as a possible cause of backache [9] and even as a predisposing factor in herniation of the fifth lumbar disc. A further implication of this bony arrangement at the level of the fifth lumbar and first sacral vertebrae deserves recognition as a direct cause of sciatica by bony pressure on the first sacral nerve.

Normally the first sacral nerve in its extrathecal course diverges only slightly from the dura as it crosses the fifth lumbar disc and passes over to the sacrum. In the two cases to be presented the first sacral nerve was found far laterally, deep in the bony recess and tightly wedged, so that it could be extricated only with the greatest difficulty. In neither case was there evidence of a herniated disc and in neither case was the disc removed.

In this paper compression of the fifth lumbar nerve in the intervertebral foramen will also be discussed, because it is felt that the mechanism of compression in principle is similar and that the lateral bony recess may be considered as a medial extension of the foramen.

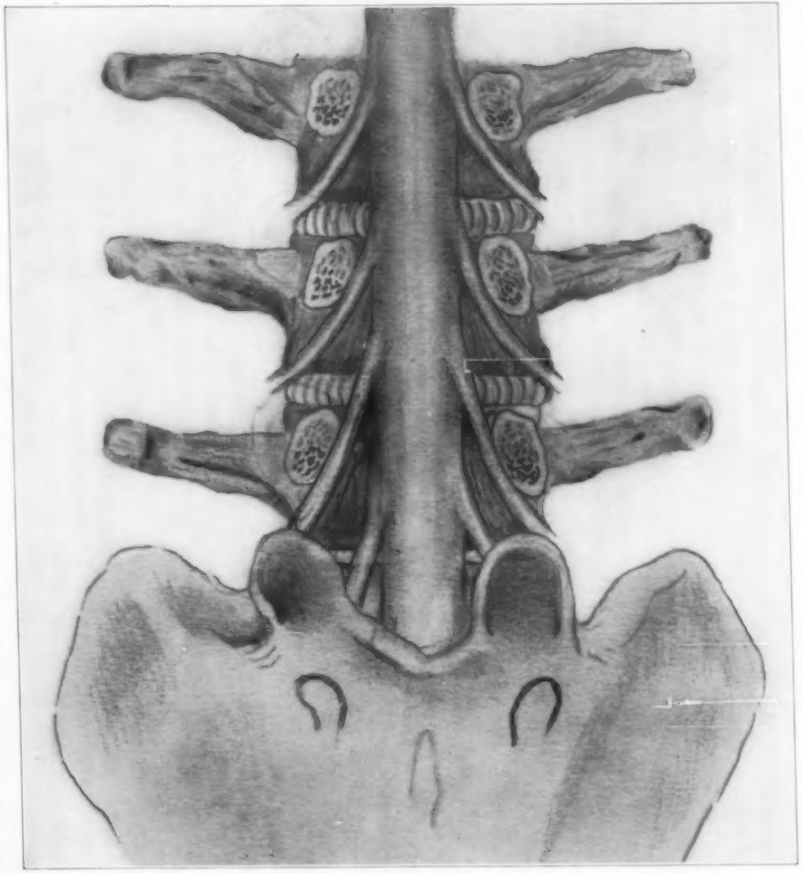

FIG. 1

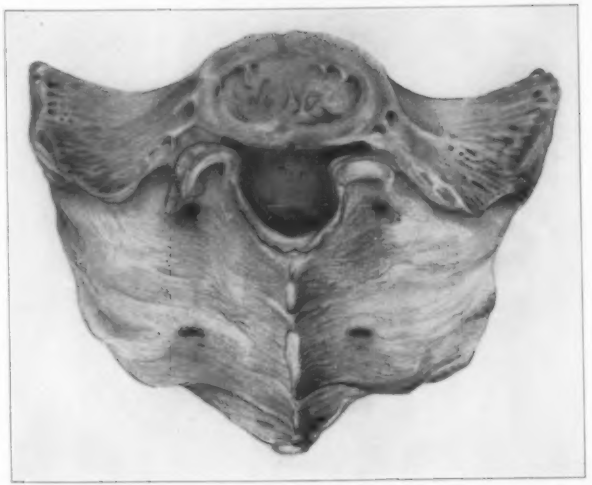

FIG. 2

Fig. 1: Postero-anterior view, with lamina and articular processes of the fifth lumbar vertebra removed. The drawing illustrates how a slightly divergent first sacral root may become caught in the lateral recess when the articular process of the sacrum lies in the frontal plane and extends toward the mid-line.

Fig. 2: View of the sacrum from above and slightly behind and to the left, showing the relationship of the articular process to the body of the sacrum. The recess can be visualized, its posterior wall being formed by the articular process of the sacrum.

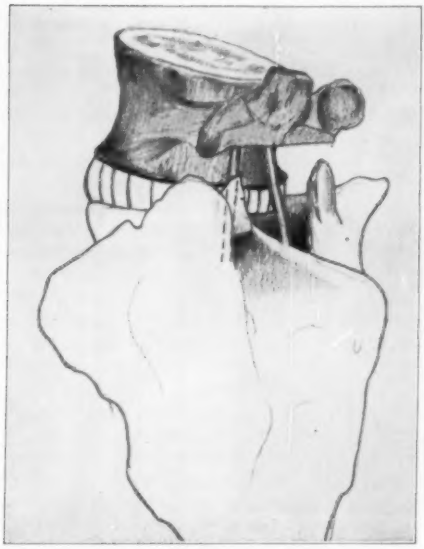

FIG. 3-A

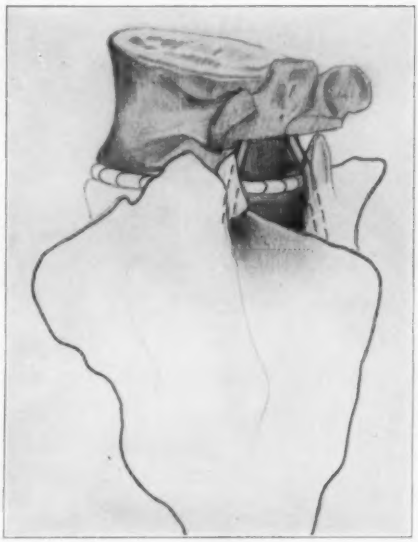

FIG. 3-B

Fig. 3-A: The drawing shows the right lateral recess as seen from the left. The inferior articular processes, the spinous process, and most of the lamina of the fifth lumbar vertebra have been removed. The dura is not shown.

The disc height is normal and the recess is ample. The first sacral nerve is far from the sacral articular process; it lies on the body of the fifth lumbar vertebra and the fifth lumbar disc.

Fig. 3-B: Similar view of the same area with a collapsed fifth lumbar disc. The recess is markedly contracted and the first sacral nerve is pinched between the articular process of the sacrum and the hypertrophic rim along the inferior border of the body of the fifth lumbar vertebra.

CASE REPORTS

CASE 1. W. W., forty-nine years old, a junior executive in a large industrial concern, was admitted to The Glens Falls Hospital on June 9, 1950, complaining of excruciating pain in the left lower extremity. In 1942 he had had fairly severe pain in the left buttock and had received diathermy for about six weeks. The pain then cleared up and he had no further difficulty until 1946, when the pain in the left buttock recurred, with radiation down the posterior aspect of the thigh as far as the knee. The pain thereafter never cleared up completely despite diathermy, osteopathic and chiropractic treatments, and later the use of a brace. In 1947 the pain became much more severe, with further extension of the radiation down the left calf into the lateral border of the foot. After the use of a brace in 1947 for about eight months, pain in the left lower extremity became fairly mild and quite tolerable until 1950, although the patient stated that he had had to guard himself very carefully and to avoid physical activity, especially lifting. Early in 1950 pain again became more severe. On this occasion the patient stated that he was unable to wear the brace because it made his pain worse. About five weeks before admission, pain became excruciating in the left lower extremity and he indicated the left buttock, posterior aspect of the thigh, lateral portion of the left calf, the left ankle, and the foot as far as the styloid process of the fifth metatarsal as the site of his pain. He described this pain as tingling in character and stated that, when he stretched his leg out, it felt as though he "were pulling on a rubber band". He remembered no pain in the back at any time. Pain in the left lower extremity was aggravated on coughing.

On examination the patient appeared to be a healthy, normally nourished man, who undressed and got up on the table without difficulty. There was flattening of the lumbar spine to such an extent that there was some reversal of the normal lumbar lordosis. Flexion was normal. Extension did not reverse the kyphosis. Tilt to the right was normal. Tilt to the left was slightly restricted in the lumbosacral area. Very mild point tenderness was present over the lumbosacral joint in the mid-line and also to the left of this area. Straight-leg-raising on the right was normal; on the left it was possible to 90 degrees, but the patient complained of a pulling sensation in the hamstrings and calf. The right ankle jerk was normal. The left was absent even on reinforcement. On sensory examination there was a band of hypo-algesia extending along the lateral aspect of the calf from the knee to the ankle into the foot along the lateral malleolus and lateral aspect of the tarsus.

Roentgenograms of the lumbosacral spine revealed marked thinning of the fifth lumbar disc with

FIG. 4-A

FIG. 4-B

FIG. 4-C

Fig. 4-A: Case 1. Anteroposterior roentgenogram showing asymmetrical facets, that on the left being mainly of the frontal type.

Fig. 4-B: Lateral roentgenogram showing marked thinning of the fifth lumbar disc, with slight retrodisplacement of the fifth lumbar body on the sacrum.

Fig. 4-C: Anteroposterior roentgenogram showing amount of bone removed operatively from the superior articular process of the sacrum and the inferior process of the fifth lumbar vertebra on the left.

retrodisplacement of the fifth lumbar body on the sacrum (Fig. 4-B).

Skin traction was applied to both lower extremities for nine days and very slight improvement resulted. The patient wished to go home, so that he could be present at his son's graduation from high school and he was discharged. The pain was so excruciating, however, that he was readmitted to the Hospital two days later and on the following day operation was performed. Myelography was not carried out because it was believed that this was a definite case of herniation of the fifth lumbar disc on the left.

At operation the spinal canal was entered on the left at the fifth lumbar interspace. On inspection the canal appeared clear. There was a normal-appearing theca and no disc protrusion could be seen. The first sacral nerve, however, could not be seen; after considerable exploration it was located laterally, in a bony recess between the articular process of the sacrum and the body of the fifth lumbar vertebra. It was wedged into the recess very tightly and it was only with the greatest difficulty that it could be extricated with a narrow-edged dura retractor. A large section of the inferior articular process of the fifth lumbar vertebra and of the articular process of the sacrum was then cut off with an osteotome and the recess was eliminated (Fig. 4-C). Despite the fact that this apophyseal joint was largely destroyed, no spine fusion was carried out. It was felt that there was already a firm fibrous ankylosis at the anterior joint, since no motion could be demonstrated at the time of operation. No disc protrusion was found and, in fact, all that remained of the posterior disc was a thin, firm, very slightly elevated line which could not be entered even with the small curette. The postoperative course was uneventful and the patient was discharged from the Hospital in nine days. He has continued to be very well and has been symptom-free for more than three years. He has no restriction of activities and does not wear a back support.

FIG. 5

Case 2. Lateral roentgenogram, showing slight thinning of the third, fourth, and fifth lumbar discs, with hypertrophic changes.

CASE 2. F. V., a male, aged fifty-five, was first seen on July 6, 1950. He gave a history of injury in May 1945 when he experienced severe pain in the back on lifting a sixty-pound weight. He was hospitalized for three weeks at that time and remained in bed at home for seven or eight weeks longer. He had been unable to do any work since that time because of pain in the left lower back. There had been no radiation into the lower extremities. He was finally awarded a lump-sum settlement in compensation and moved to northern New York State. He bought his wife a restaurant and did a little light work in helping her.

There had been a history of previous injury in 1941 when he had experienced a sudden pain in the left lower back while hanging a door. He was confined to bed in the plant infirmary at that time for a week and then returned to work.

The examination when he was first seen in 1950 revealed few abnormal findings. Flexibility of the spine was almost normal. Mild percussion tenderness was present over the spinous process of the fifth lumbar vertebra and straight-leg-raising on both sides was to just 90 degrees. On the left, however, the patient complained of some pain in the mid-line of the lower back. The knee jerks were equal and active. The right ankle jerk was present on reinforcement but was less strong than the left. Sensory examination of the lower extremities failed to reveal hypo-algesia or hypo-aesthesia.

Roentgenograms of the lumbosacral spine revealed spur formation at the anterior margins of the opposing borders of the third, fourth, and fifth lumbar vertebral bodies. There appeared to be some narrowing of the third, fourth, and fifth lumbar discs (Fig. 5).

When he was seen about five months later he stated that pain in the back had remained essentially unchanged. In the last several days, however, he had also begun to complain of pain radiating into the left buttock and he stated that the pain was worse when he walked. Examination of the spine at that time showed no deformity. Aside from mild restriction of forward flexion, the spine was normally flexible. Mild tenderness was present over the lumbosacral interspace in the mid-line and also over the left greater sciatic notch. Straight-leg-raising was possible on both sides to 90 degrees, with pain referred to the lumbosacral interspace in the mid-line. The right ankle jerk was absent, but the left was normal. The knee jerks were

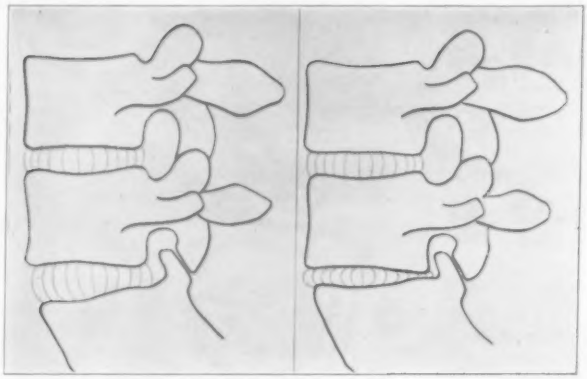

FIG. 6-A FIG. 6-B

Fig. 6-A: Schematic drawing showing the normal position of the lateral recess when the articular process of the sacrum lies in the frontal plane.

Fig. 6-B: Showing narrowing of the lateral recess when the articular process of the sacrum lies in the frontal plane and the fifth lumbar disc becomes thinned through degeneration.

Fig. 7-A: Schematic drawing outlining the width of the normal intervertebral foramen when the articular process of the sacrum is of the sagittal type.

Fig. 7-B: Showing narrowing of the fifth lumbar intervertebral foramen in the presence of degenerative disease of the fifth lumbar disc and thinning of the disc.

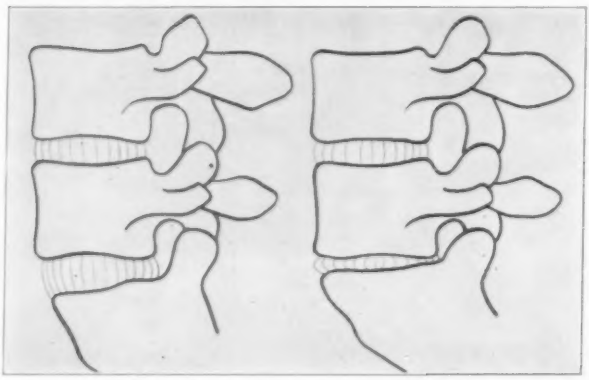

FIG. 7-A FIG. 7-B

equal and active and sensory examination was again negative. There was no evidence of impairment of the extrinsic muscles of the feet.

Because of the long history of pain and disability and despite the relative paucity of signs, the patient was admitted to The Glens Falls Hospital. Myelography was carried out on November 21, 1950, under the direction of the roentgenologist, Dr. Richard C. Batt. The findings were completely normal and the patient went home shortly thereafter.

The patient was observed at intervals and the pain fluctuated. Occasionally the lumbar spine showed definite flattening and restriction, but usually flexibility was fairly good. At examination on August 6, 1951, the patient for the first time complained of pain radiating into the right buttock and stated that his activities had been even more restricted than previously. At that time his spine showed a double scoliotic curve, with the convexity to the left in the lower thoracic and upper lumbar regions and to the right in the lumbosacral region. There was a moderate list to the left. There was some reversal of the usual lumbar lordosis. Tilt to the left was slightly restricted; that to the right was markedly so and was painful. Straight-leg-raising on the left was normal, whereas on the right it was considerably restricted and painful. The knee jerks were equal and active. The left ankle jerk was normal; the right was absent. Sensory examination of the lower extremities was again negative.

At this time we became convinced that the patient had some type of root compression, probably at the fifth lumbar level. He was readmitted to the Hospital and operation was performed on September 18, 1951. The spinal canal was entered at the right fifth lumbar interspace. The canal appeared quite clear, with a smooth disc surface and a normal-appearing theca which retracted easily. The first sacral nerve could not be seen, but after some inspection it was found lying in a narrow lateral recess between the body of the fifth lumbar vertebra and the articular process of the sacrum. It was wedged in quite tightly and was extricated only with considerable force, again by means of a narrow-edged dura retractor. A large section of the superior articular process of the sacrum was removed with an osteotome and a mallet. The root was then seen to lie freely in its normal position. A similar exploration was carried out on the left side at the same level. The findings were identical and the identical procedure was carried out.

In this case a spine fusion of the Hibbs type was performed between the fifth lumbar vertebra and the sacrum, because of the instability which had resulted from the partial destruction of the posterior joints and because of the fact that considerable motion remained between the fifth lumbar vertebra and the sacrum. The postoperative course was uneventful and the patient was discharged from the Hospital, wearing a brace, on November 3, 1951.

The patient continued to be well and subsequent roentgenograms showed an apparently solid fusion

of the fifth lumbar vertebra to the sacrum. Pain in the buttocks and low back disappeared following surgery and, when he was last seen, on May 6, 1953, the patient was symptom-free except for the complaint of mild aching pain to the right of the second lumbar vertebra after he "had been up on his feet for a length of time and became tired". Examination at that time showed no tenderness over the back or buttocks. Forward flexion of the lumbar spine was only mildly restricted, with incomplete reversal of the lumbar curve, and hyperextension was somewhat restricted; neither motion was painful. Tilt to either side also was restricted in the lower lumbar region. Straight-leg-raising was possible on both sides to past 90 degrees without pain. The knee jerks were equal and active. The right ankle jerk was absent even on reinforcement. The left was hypo-active. The patient appeared to be very happy about the result. He had not gone back to heavy work, although he had been quite active around his own restaurant.

REVIEW OF THE LITERATURE

The lesions which may cause pain in the low back with sciatic radiation are many. Cases have been described with congenital defects, as well as cases of neoplastic, arthritic, infectious, or metabolic origin. However, ever since the classic paper of Mixter and Barr in 1934, herniation of the lower lumbar discs with compression of the involved nerve root has been recognized as the most common cause of sciatica. The large number of published reports of operations for this condition since publication of that article indicates the increasing extent to which the condition has been recognized. Other causes of compression of the lower lumbar roots have recently been recorded. Ethelberg and Riishede have described malformation of the lumbar spinal roots and sheaths in the causation of low-back pain and sciatica. In a recent monograph by Tarlov, cysts of the sacral nerve roots have been established as another cause.

Compression of the lumbar nerves within the intervertebral foramina by lateral herniation of a disc or by pinching of the nerve between the bony walls of the foramen has been described in isolated papers. Danforth and Wilson, in a clear anatomical demonstration in 1925, showed that the fifth lumbar nerve is relatively large and the intervertebral foramen through which it emerges relatively small. Larmon in ten autopsy specimens found four with narrowed, degenerated fifth lumbar discs and narrowing of the fifth lumbar foramen with compression of the fifth lumbar nerve. In 1932 Williams described the mechanism of closure of the fifth lumbar foramen by subluxation of the involved facets after collapse of the fifth lumbar disc. He also showed that backward displacement of the fifth lumbar vertebra took place in many of these cases and stated that subluxation occurred only when the posterior articulations lay in the frontal or oblique planes, but not when they lay in the sagittal plane. The correlation between facets lying in the frontal plane and backward displacement of the fifth lumbar vertebra was discussed by Hibbs and Swift in 1929; these authors attributed instability of this joint to such a factor. Fletcher in 1947 showed that backward displacement of the fifth lumbar vertebra in degenerative disease of the fifth lumbar disc with thinning of the disc must take place in the presence of facets lying in the frontal plane, because these facets also lay in the plane directed downward and backward. Hadley in 1936 demonstrated that, when disc degeneration with thinning of the disc takes place in the thoracic or upper lumbar regions, a kyphos is usually produced, because "the posterior articulations do not slip past each other". Thinning of the disc in the lower lumbar region, however, "usually produces a subluxation of the apophyseal or posterior articulations".

Surgical exposure of the intervertebral foramen is a relatively recent development. Facetectomy was performed by Putti and was first reported by him in 1927. Facetectomy was reported in a single case by Williams and Yglesias and also by Mitchell. In a series of thirty-five facetectomies reported in 1945, Briggs and Krause demonstrated that the operation is quite feasible and the results in selected cases are satisfactory. In their series they found twenty-two cases in which there was diminution of the foraminal space secondary to diminution of the intervertebral disc.

PATHOLOGICAL CONSIDERATIONS

Recent pathological studies, such as those by Coventry, Ghormley, and Kernohan, place greater emphasis on progressive degenerative processes in the intervertebral discs and it is considered that even in younger persons degenerative lesions predispose to the posterior protrusions which may occur with acute trauma. In addition, as was pointed out by Lindblom and Hultqvist, healing both in the degenerative lesions within the disc and of the extruded material posteriorly takes place not so much by fibrosis as by absorption. This would account for the fact that, in patients with a long history of pain, at operation the surgeon will frequently find only a small remnant of fibrotic tissue, which is all that remains of the original protrusion; this remnant is usually adherent to the involved spinal nerve. Certainly in older patients it is most unusual to find a large amount of extravasated disc material in the spinal canal. In this group posterior protrusions are probably not so common as the degenerative lesions of the lower lumbar discs without posterior protrusions.

When there is degenerative disease of the lower lumbar region, it should not be surprising to find compression of either the fifth lumbar nerve in the foramen or of the first sacral nerve in the lateral bony recess as a cause of sciatic pain in older patients. This may be expected, because in the fifth lumbar disc the arrangement of the articular facets is usually such that there is no bony meshing to retard collapse of the disc; in addition, the intervertebral foramen is already small compared with the size of the fifth lumbar root and in many cases a bony recess of the spinal canal is already present. This is true especially if the fifth lumbar vertebra is displaced backward on the sacrum or if a hypertrophic bony rim has developed on the inferior border of the involved body posteriorly or laterally.

In Case 1, there is no question that this patient had advanced degenerative disease of the fifth lumbar disc, with complete collapse of the disc and backward displacement. It is worthy of note that at operation this patient appeared to have a firm fibrous ankylosis and that, despite extensive operative destruction of the apophyseal joint on one side, the patient has remained symptom-free without a spine fusion and without a back support.

The appearance of the first sacral nerves in the two cases described should be mentioned. After the involved nerves had been pulled out of the bony recess, they had a normal appearance; they were white and smooth and showed no flattening or adhesions.

VALUE OF MYELOGRAPHY

The myelogram in Case 2 was negative and indeed the normal appearance of the dura at the operating table gave no reason why this should not have been so. In Case 1 myelography was not carried out, but should also have been negative, judging by the appearance of the thecal sac.

When compression of a nerve has taken place lateral to the dura in the lateral recess or intervertebral foramen, whether by a disc protrusion or by the impingement of bone or of other structures, myelography will probably not be useful and a negative myelogram cannot rule out such possibilities.

CLINICAL IMPLICATIONS

In the presence of degenerative disc disease of the fifth lumbar disc in older patients without herniation or with earlier absorbed herniations and with collapse or narrowing of the disc, with or without posterior displacement of the fifth lumbar body, compression of either the fifth lumbar nerve in the intervertebral foramen or of the first sacral nerve in the lateral bony recess may be expected in a certain number of cases. It is known that many of the unsatisfactory operative results are in cases of "degenerated" discs in which no herniation is found [7]. We wonder whether in this group we are overlooking compression

of either the fifth lumbar root in the foramen or of the first sacral nerve in the lateral bony recess. Briggs and Krause believed that, if the surgeon makes a preoperative diagnosis of root compression and fails to find a posterior protrusion of the fourth or fifth disc in the spinal canal, his exploration is not complete unless he follows the fifth lumbar nerve through its course in the foramen — that is, unless he unroofs the foramen. This is true especially if the preoperative roentgenograms demonstrate a definite thinning of the fifth lumbar disc and if the patient is in the older age group. In other words, the operation should be considered primarily a root exploration and the exposure should be planned to demonstrate the presence and condition of the root. The technique of facetectomy, or foraminotomy as Briggs and Krause prefer to call it, should not be a formidable one for a surgeon experienced in entering the spinal canal. However, in most cases, after it has been carried out, a spine fusion at the involved level should be performed. A technical consideration which should be mentioned is that probing of the intervertebral foramen, as carried out by Briggs with a bent probe, is very difficult if not impossible, in the presence of a deep lateral recess unless the medial portion of the articular process of the sacrum is removed first. On the question of foraminotomy it might be added that it is rarely necessary to carry the exposure as far as the outer margin of the foramen or into the soft parts lateral to it.

The importance of good exposure is to be emphasized. For example, if in the two cases cited the spinal canal had not been well exposed, the failure to visualize the first sacral nerve might not have assumed too great importance. However, its absence from the usual position, when definitely confirmed, must have great importance, as these two cases well illustrate. In principle, bony compression of the first sacral nerve in the lateral recess is similar to compression of the fifth lumbar nerve in the foramen. The former, of course, will be easier to find at the operating table and should not be missed if the exposure of the spinal canal is adequate and if the possibility of this lesion is kept in mind. Once the absence of the first sacral nerve from its normal position has been confirmed and the nerve is seen in the recess, it is advisable to pull the nerve out of the recess, although this will not be easy if it is tightly wedged. Eliminating the recess will be a simple technique, once the nerve has been retracted medially. It would be difficult to avoid damage to the first sacral nerve if the sacral articular process is removed without the nerve being retracted first.

In addition, in view of Tarlov's recent discovery of cysts of sacral nerve roots as a cause of sciatica, we would now consider the advisability, in some cases, of removing a section of the sacral lamina on the involved side to rule out this cause of compression of the first or second sacral nerves.

CONCLUSIONS

1. There exists a lateral bony recess of the spinal canal at the level of the fifth lumbar disc. This is fairly deep in some individuals.

2. The lateral recess may be narrowed from before backward by degeneration and thinning of the fifth lumbar disc, especially if there is backward displacement of the fifth lumbar body or if there is a hypertrophic rim on its inferior border.

3. The first sacral nerve can become caught in this recess and sciatica may result.

4. Myelography will probably not be helpful in diagnosing this lesion.

5. Compression of the first sacral nerve in the lateral recess or of the fifth lumbar nerve in the intervertebral foramen should be considered as possibilities in patients of about fifty or over with sciatica, especially if roentgenograms show thinning of the fifth lumbar disc.

6. It is useful to conceive of disc surgery in this age group in terms of root exploration rather than simple removal of a herniated disc.

NOTE: The author wishes to acknowledge the careful work of Mr. Loren H. Blackburn in making the drawings used in this article.

REFERENCES

1. Badgley, C. E.: The Articular Facets in Relation to Low-Back Pain and Sciatic Radiation. J. Bone and Joint Surg., **23:** 481–496, Apr. 1941.
2. Briggs, Henry: Personal communication.
3. Briggs, Henry, and Krause, Jacob: The Intervertebral Foraminotomy for Relief of Sciatic Pain. J. Bone and Joint Surg., **27:** 475–478, July 1945.
4. Coventry, M. B.; Ghormley, R. K.; and Kernohan, J. W.: The Intervertebral Disc: Its Microscopic Anatomy and Pathology. Part II. Changes in the Intervertebral Disc Concomitant with Age. J. Bone and Joint Surg., **27:** 233–247, Apr. 1945.
5. Danforth, M. S., and Wilson, P. D.: The Anatomy of the Lumbo-Sacral Region in Relation to Sciatic Pain. J. Bone and Joint Surg., **7:** 109–160, Jan. 1925.
6. Ethelberg, Sven, and Riishede, John: Malformation of Lumbar Spinal Roots and Sheaths in the Causation of Low Backache and Sciatica. J. Bone and Joint Surg., **34-B:** 442–446, Aug. 1952.
7. Fletcher, G. H.: Backward Displacement of Fifth Lumbar Vertebra in Degenerative Disc Disease. The Significance of the Difference in Anteroposterior Diameters of the Fifth Lumbar and First Sacral Vertebrae. J. Bone and Joint Surg., **29:** 1019–1026, Oct. 1947.
8. Hadley, L. A.: Apophyseal Subluxation. Disturbances in and about the Intervertebral Foramen Causing Back Pain. J. Bone and Joint Surg., **18:** 428–433, Apr. 1936.
9. Hibbs, R. A., and Swift, W. E.: Developmental Abnormalities at the Lumbosacral Juncture Causing Pain and Disability. A Report of One Hundred and Forty-Seven Patients Treated by the Spine Fusion Operation. Surg., Gynec., and Obstet., **48:** 604–612, 1929.
10. Horwitz, Thomas, and Smith, R. M.: An Anatomical, Pathological and Roentgenological Study of the Intervertebral Joints of the Lumbar Spine and of the Sacroiliac Joints. Am. J. Roentgenol., **43:** 173–186, 1940.
11. Larmon, W. A.: An Anatomic Study of the Lumbosacral Region in Relation to Low Back Pain and Sciatica. Ann. Surg., **119:** 892–896, 1944.
12. Lindblom, K., and Hultqvist, G.: Absorption of Protruded Disc Tissue. J. Bone and Joint Surg., **32-A:** 557–560, July 1950.
13. Mitchell, C. L.: Lumbosacral Facetectomy for Relief of Sciatic Pain. A Case Report. J. Bone and Joint Surg., **16:** 706–708, July 1934.
14. Mixter, W. J., and Barr, J. S.: Rupture of the Intervertebral Disc with Involvement of the Spinal Canal. New England J. Med., **211:** 210–215, 1934.
15. Putti, V.: Lady Jones Lecture on New Conceptions in the Pathogenesis of Sciatic Pain. Lancet, **2:** 53–60, 1927.
16. Tarlov, I. M.: Sacral Nerve-Root Cysts. Another Cause of the Sciatic or Cauda Equina Syndrome. Springfield, Illinois, Charles C. Thomas, 1953.
17. Williams, P. C.: Reduced Lumbosacral Joint Space. Its Relation to Sciatic Irritation. J. Am. Med. Assn., **99:** 1677–1682, 1932.
18. Williams, P. C., and Yglesias, Luis: Lumbosacral Facetectomy for Post-Fusion Persistent Sciatica. J. Bone and Joint Surg., **15:** 579–590, July 1933.

DISCUSSION

An Analysis of End Results of Surgical Treatment of Major Injuries to the Ligaments of the Knee

(Continued from page 13)

reconstruction of the anterior cruciate ligament in a person forty-five or fifty-five years old who is not going to engage in any strenuous physical pursuit,—such a person does not need the cruciate ligament. On the other hand, the athlete in modern life looks on athletics as his career. I do not refer to the period he is in college only. These fellows go on to work in physical education in the universities, and become coaches and teachers, or they become professional players. If you tell this sort of man that, since he has hurt himself, he must do something else with his life, it is like saying to an intern that he cannot continue in medicine.

Rehabilitation is the goal of the modern orthopaedist, and all measures within reason should be utilized to make rehabilitation complete.

TWO-JOINT MUSCLES OF THE THIGH*†

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INTRODUCTION

This presentation will be restricted to those few muscles which act over both the hip and the knee joints. These muscles are the rectus femoris, the semimembranosus, semitendinosus, the biceps femoris, the sartorius, and the gracilis.

Certain actions of these muscles are well known and are stated in the standard textbooks of anatomy. For example, when the leg is being carried forward, the rectus femoris is known by its shortening to contribute both to flexion of the hip joint and to extension of the knee joint (Fig. 1,*A*). When the leg is being carried backward, the hamstring muscles shorten and, consequently, contribute both to extension of the hip joint and flexion of the knee joint (Fig. 1,*B*).

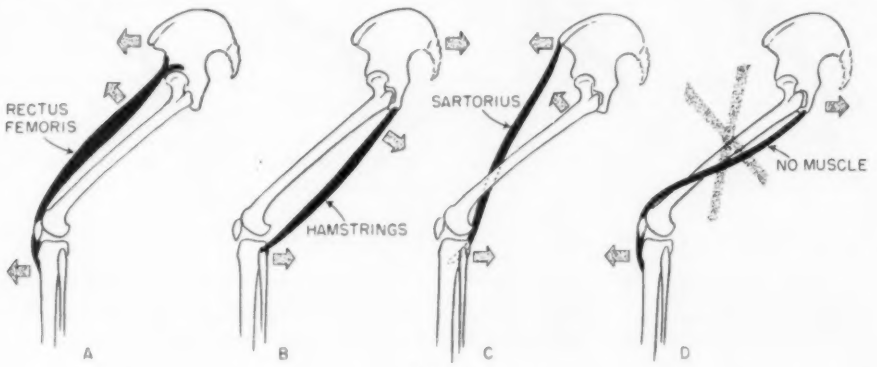

FIG. 1

Drawing illustrating the actions of those thigh muscles which bridge both the hip and the knee.

The attachments, that is, the origin and the insertion, of the rectus femoris lie in front of a vertical plane passing through the length of the trunk and the inferior extremity. Tension transmitted between the origin and the insertion would tend, therefore, to approximate these attachments. The actions would be merely to pull the parts forward: to flex the thigh or trunk, and to extend the leg (Fig. 1,*A*). Likewise, the attachments of the hamstring muscles lie posterior to a vertical plane passing through the length of the trunk and inferior extremity. Shortening of these muscles would tend, therefore, to approximate the origin and insertion or to carry the parts backward, — that is, to extend the thigh or trunk and to flex the leg (Fig. 1,*B*). If the sartorius acts only to cause approximation of the origin and insertion, it must always tend to flex simultaneously the hip and knee joints (Fig. 1,*C*).

If this concept of the action of the rectus femoris, the hamstrings, and the sartorius is correct, we must recognize that the rectus femoris is well adapted to such movements as kicking a football but is poorly adapted to raising the leg from one stair step to the step

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† Aided by a grant from The National Foundation for Infantile Paralysis, Inc.

above. The hamstrings function efficiently in propelling the body forward when the foot is striking the take-off marker in the broad jump, but they function inefficiently when the body weight is being raised from a chair. The sartorius functions efficiently only when the hip and knee joints are to be flexed simultaneously, as during a withdrawal reflex.

However, the rectus femoris and the hamstrings have certain adaptations in structure which contribute to movements of the hip and knee joints under conditions which are very different from the ones mentioned above, — that is, during certain parts of the cycle of walking or running these muscles can participate in movements of the hip and knee joint which apparently cannot be explained by pull that is transmitted entirely from the proximal point of origin to the distal point of insertion. As is indicated in Figure 2,*A*, the thigh can be moved forward (flexed) even though the leg is not being moved forward (extended) on the thigh. As is shown in Figure 2,*C*, the thigh can be extended when the leg is not being flexed. When these movements are being carried out, one of the three following alternatives must be true:

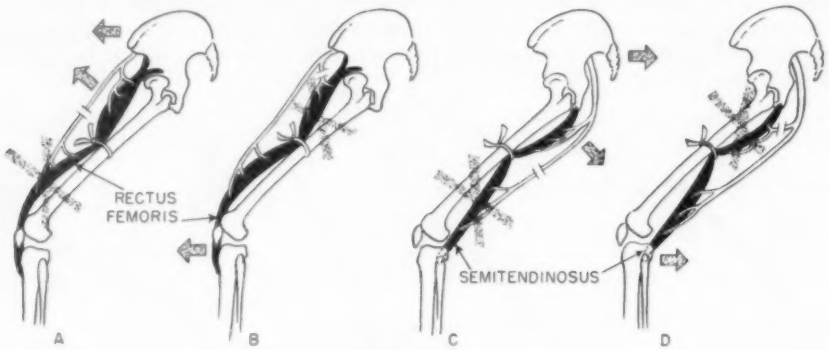

FIG. 2

Drawing illustrating how the rectus femoris and the semitendinosus can act on the joint at one end of the femur without acting on the other joint. The separate action of the rectus femoris on the hip joint is illustrated in *A*, its separate action on the knee in *B*. The separate action of the semitendinosus on the hip joint is illustrated in *C*, its separate action on the knee joint in *D*.

1. The rectus femoris and hamstrings do not shorten when they might produce undesirable movement at either the hip or the knee joint.

2. Other muscles expend energy to overcome the undesirable action of the rectus femoris and hamstrings at either the hip or the knee joint.

3. The rectus femoris and hamstrings can contribute to movement at one joint without interfering with movement at the other joint.

To study the possibility that these muscles might have an unrecognized mode of action, the investigation was divided into two main parts: (1) morphological studies of these muscles in human cadavera; and (2) functional studies of these muscles in dogs.

MORPHOLOGICAL STUDIES IN THE HUMAN

The hamstring muscles have some characteristics in common, but differ greatly in their morphology and in their function.

Semitendinosus

Morphology

The semitendinosus is morphologically a single muscle. Its morphological and physiological characteristics can be most easily understood, however, if it is considered as two muscles attached to an intervening tendinous inscription. This inscription may be thought

of as a strengthening of the fascia lata, which serves as a somewhat yielding insertion for the muscle fibers of the proximal part of the muscle, and the origin for the fibers composing the distal portion of the muscle.

The fibers which make up this muscle are long (Fig. 3). The average length of the fibers which arise from the ischial tuberosity and insert onto the inscription is about five centimeters. The average length of the fibers which arise from the tendinous inscription and insert onto the tibia is approximately ten centimeters. This muscle, therefore, has all of the characteristics of a digastric muscle.

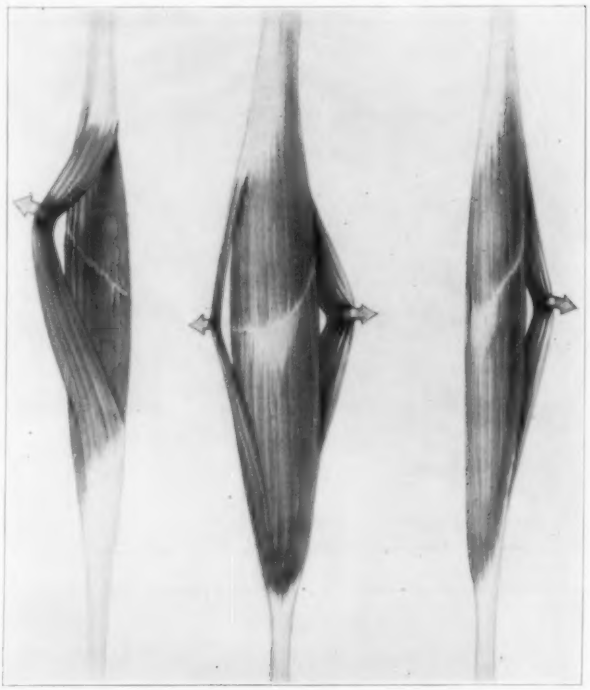

FIG. 3

Drawing illustrating the arrangement and relative length of the fibers of the human semitendinosus.

Nerve Supply

Two nerves to the semitendinosus are present; the uppermost arises from the tibial division almost opposite the ischial tuberosity. It promptly divides and passes deep to the origin of the biceps femoris. The *upper branch* enters the middle of the posterior surface of the semitendinosus close to the tendon of origin, and passes downward and medialward about three centimeters. The *lower branch* enters the lateral border of the semitendinosus at about the level of the termination of the upper branch and divides into two filaments, both passing downward and medialward to supply the muscle belly as far as its middle. The *second nerve* to the semitendinosus arises from the tibial division at the level of the upper and middle thirds of the thigh. It originates in common with the nerve to the semimembranosus, but rather quickly separates from it. Dividing into two branches, it enters the deep surface below the middle of that muscle. The *first branch* enters just medial to the mid-line, and its filaments then descend medially to supply the upper medial portion of the lower half of the muscle. The *second branch* continues downward, entering the lateral side of the muscle about the junction of the middle and lower thirds, and continues almost to the tendon, supplying the lowermost portion of the muscle.

Variations

A number of variations occur in the structure of the semitendinosus. The most frequent variation is the presence of a number of fascicles which bridge the tendinous inscription. They originate proximal to the inscription and insert onto the tendon distal to the inscription. One or more fascicles may extend from the body of the muscle to the fascia on the back of the thigh. This muscle very rarely has a small femoral attachment, a condition characteristic of many birds.

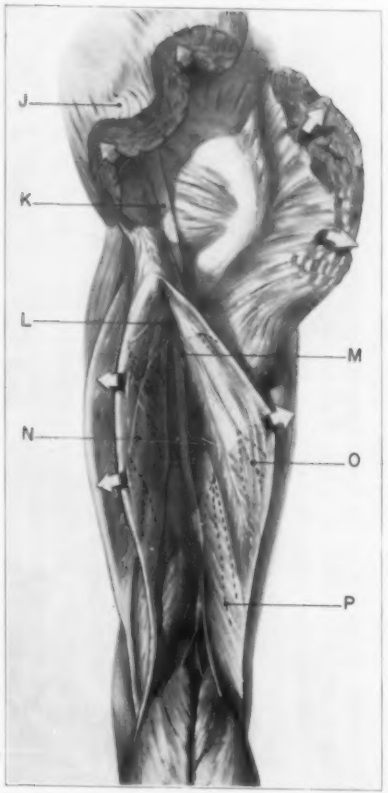

FIG. 4

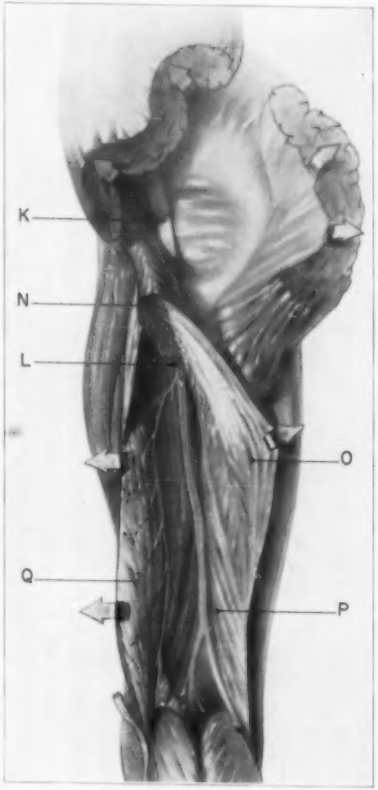

FIG. 5

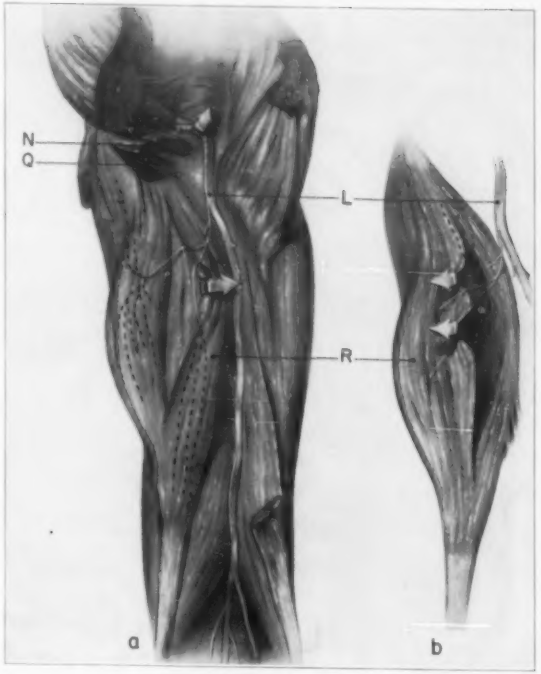

FIG. 6

Figs. 4 through 9 illustrate the innervation of those muscles which bridge the hip and knee joints. In each figure the course of the nerve fibers within the muscles is indicated by the dotted lines. The letters designate the different muscles and nerves as follows: *A*, sartorius; *B*, nervus femoralis; *C*, rectus femoris; *D*, vastus medialis; *E*, vastus intermedius; *F*, vastus lateralis; *G*, adductor longus; *H*, gracilis; *I*, nervus tibialis; *J*, glutaeus maximus; *K*, sciatic nerve; *L*, tibial portion of sciatic nerve; *M*, nervus peroneus communis; *N*, semitendinosus; *O*, biceps, caput longum; *P*, biceps, caput breve; *Q*, semimembranosus; *R*, adductor magnus.

Fig. 4: Innervation of semitendinosus and biceps femoris. Fig. 5: Innervation of semimembranosus. Fig. 6: Innervation of adductor magnus.

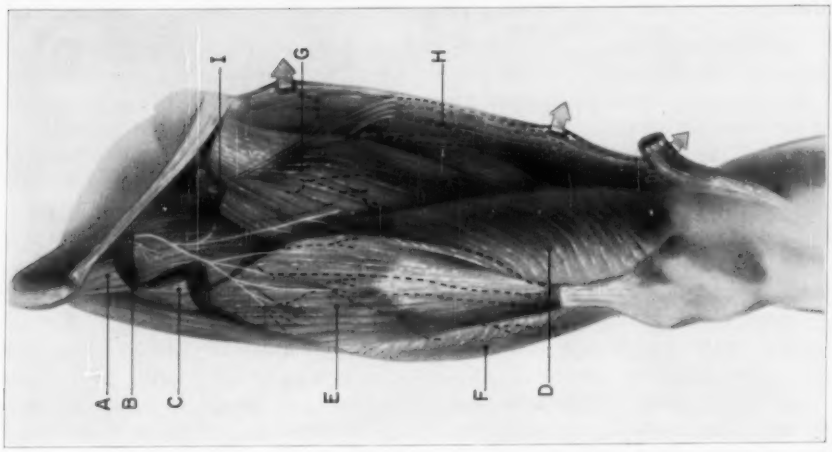

FIG. 9
Innervation of gracilis.

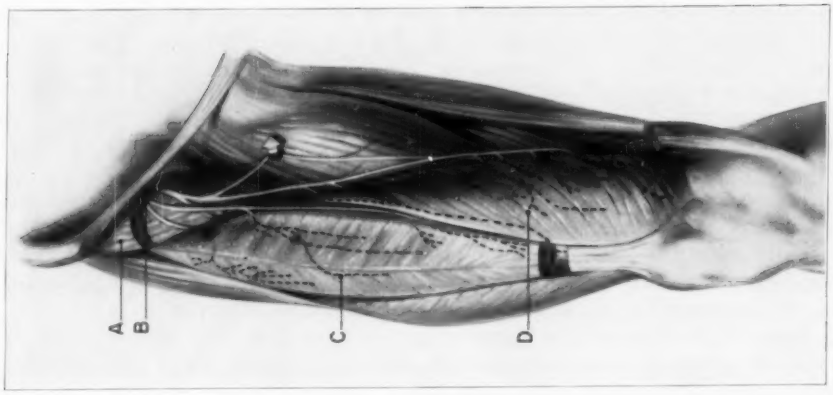

FIG. 8
Innervation of rectus femoris.

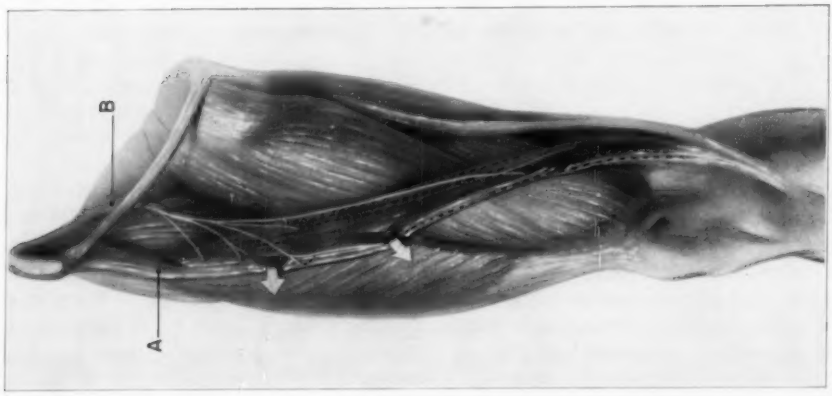

FIG. 7
Innervation of sartorius.

Semimembranosus

Morphology

The semimembranosus (Fig. 4) appears to be morphologically a single muscle. It is composed of short fibers so arranged as to crowd a maximal number into a minimal space. Some of the fibers are bipennate in arrangement and others are unipennate. The average length of the fibers is about 5.5 centimeters. The long, flat tendon of origin lies beneath the proximal half of the semitendinosus and arises from the more lateral of the two heads or facets on the back of the ischial tuberosity. The proximal portion of this tendon of origin usually adheres to both the tendon of the adductor magnus and the tendon of origin of the biceps femoris. This long tendon of origin continues somewhat distal to the center of the belly of the muscle. The long tendon of insertion begins at a point somewhat proximal to the middle of the muscle belly and passes along the medial and deep surface of the muscle toward its multiple insertion. A part of this tendon of insertion is attached directly to the back of the medial condyle of the tibia. Another portion of the tendon of insertion expands into the capsule of the knee joint, the medial condyle of the femur, and the more proximal portion of the tibial collateral ligament. A small portion of this tendon of insertion attaches to the fascia of the popliteus muscle. The tendon of insertion is rather broad. Occasionally, a gap divides the tendon into two portions, but in those bodies in which there is no gap, the two portions may be easily separated.

Nerve Supply

The nerve to the semimembranosus (Figs. 5 and 10-E) is usually a single nerve which arises in common with that to the distal portion of the semitendinosus, as noted above. Shortly after the separation of these two nerves, the posterior nerve to the adductor magnus, which runs with it, is separated from the nerve to the semimembranosus at the point where the nerve lies on the posterior surface of the adductor magnus. Therefore, the nerve to the semimembranosus continues downward and forward on the deep (or lateral) surface of that muscle almost to its insertion, supplying in its course a series of five branches which enter the deep surface of the muscle. The uppermost branch penetrates just below the tendinous origin near the mid-line. The next three branches in succession enter nearer the anterior border of the muscle. The filaments of these three branches descend downward and backward to terminate near the superficial surface. One or more of these branches enters that portion of the muscle which inserts onto the posterior surface of the tibia. The lowest branch, or group of branches, enters that portion of the muscle which inserts onto the distal end of the femur or the various parts of the knee joint.

Biceps Femoris

Morphology

The biceps femoris is a double muscle, both morphologically and functionally. The *long head* arises from a common tendon, that is, it shares a tendon with the semitendinosus. This tendon originates from the more medial of the two facets on the back of the tuberosity of the ischium and from the sacrotuberous ligament. The more proximal portion of this tendon serves as a septum between the biceps and the semitendinosus, and the distal portion serves as a tendon of origin which lies on the deep surface of the muscle. The fibers of the long head of the biceps femoris are arranged in a bipennate fashion. They arise from the tendon beginning some distance caudad to the ischium. These fibers form a thick fusiform belly which is inserted into the deep surface of the tendon that appears laterally on the back or deep surface of the muscle at about the mid-point of the thigh. The muscle belly is relatively long and. consequently, continues nearly as far caudad as the lateral condyle of the femur.

The fibers of the *short head* of the biceps femoris originate directly from bone without

an intervening tendon. They arise from the lateral lip of the linea aspera, from the middle of the shaft to the point where the linea aspera bifurcates, and from the proximal two-thirds of the supracondylar line, as well as from the lateral intermuscular septum. The fibers of the short head are arranged in a parallel manner. They terminate on the deep surface of the common tendon of insertion which attaches to the superior extremity of the head of the fibula and into the lateral condyle of the tibia, as well as into the fascia of the leg.

Nerve Supply

The nerve which supplies the long head of the biceps femoris (Figs. 4 and 10-E) arises from the tibial division of the sciatic nerve about opposite the nerve to the semimembranosus and the distal portion of the semitendinosus. It divides into an upper and a lower branch. The *upper branch* almost immediately enters the muscle on its deep surface and near its mid-line. The nerve filaments descend in a lateral direction to supply the upper third of the long head. The *lower branch* enters about mid-way along the deep surface and near the mid-line of the muscle; the filaments run downward and terminate near the superficial aspect of the long head. The longest of these filaments terminates near the fusion of the long and short heads of the biceps femoris. The nerve fibers which are distributed to the long head originate from the first, the second, and the third sacral nerves.

The nerve which supplies the short head of the biceps femoris arises from the peroneal nerve, a little above the middle of the thigh, runs down the deep surface of the long head, passing between the long and short heads, and enters the superficial surface of the latter a little distal to the uppermost part of its origin. Soon after the nerve penetrates the substance of the short head, it divides into three branches which run distalward and lateralward toward the point of fusion of the long and short heads of the muscle. The nerve fibers which are distributed to the short head arise from the fifth lumbar and the first and second sacral nerves.

Variations

Many minor variations occur in the biceps femoris. One of the most frequent is the presence of an inscription in the long head, similar to the inscription in the semitendinosus, but less well developed. When this inscription is present, one nerve branch supplies the muscle fascicles located proximal to the inscription and another nerve branch supplies the fascicles distal to it. In some of those instances in which there is a tendinous inscription across the long head, additional fascicles may be continued distalward to attach into the sural fascia. Aberrant fascicles originate from other areas, such as the coccyx, sacrum, ischial tuberosity, the sacrotuberous ligament, or even the deep surface of the glutaeus maximus. Rarely do these fascicles extend as far distal as the Achilles tendon. The short head of the biceps likewise varies. It may be divided into two distinct parts or layers, and one or more of these layers may be isolated from the long head of the biceps. The short head of the biceps may not share the common tendon of insertion.

Rectus Femoris

Morphology

The rectus femoris characteristically arises by two tendons. The anterior or straight tendon originates from the anterior inferior spine of the ilium. The posterior or reflected tendon arises from the posterior superior surface of the rim of the acetabulum. These two tendons of origin may remain relatively separate or they may form an arch. From these two tendons, an aponeurosis passes downward upon the superficial surface of the muscle toward its middle third and serves as the origin for the individual muscle fascicles. This aponeurosis of origin narrows as it descends and continues into the substance of the muscle as an intramuscular tendon. The tendon of insertion appears on the posterior surface of

FIG. 10-A
Sartorius.

FIG. 10 B
Rectus femoris.

FIG. 10-C
Gracilis.

Figs. 10-A to 10-F: Illustrating the distribution of the nerves within certain muscles of the thigh, as demonstrated by maceration and dissection.

the muscle, at approximately the middle of the muscle belly, and extends as a somewhat curved aponeurosis. The more lateral portion of this aponeurosis becomes a strong band which is attached to the proximal extremity or border of the patella. The more medial portion of the muscle is intimately related to the fascia lata, to the adjacent sartorius, and to the adductor longus. At the point along the thigh where the surfaces of the rectus femoris, the sartorius, and the adductor longus are in intimate relationship, the fascia lata and medial intermuscular septum are particularly well developed. Those fibers which arise along the upper and lateral portions of the muscle terminate in the toughened connecting tissue, which extends inward as the fascia lata, and in the intermuscular septum at this position. The muscle fibers which originate from the upper portion toward the medial aspect of the aponeurosis, or central tendon of origin, are joined by all of the fibers originating in the lower part of the muscle. This is the largest part of the belly of the muscle, and these fibers continue distalward in a somewhat bipennate form to attach to the front and sides of the tendon of insertion.

Nerve Supply

Usually two nerves enter the rectus femoris (Figs. 8 and 10-B). When there is only one nerve, it divides before entering the substance of the muscle. The *first nerve* courses laterally between the rectus femoris and the vastus medialis to enter the muscle medial to its mid-line in the lower portion of the upper third, where it breaks into two branches. The first branch turns upward a short distance and lies deep in the substance of the muscle, whereas the second branch continues downward to terminate near the lateral border. The

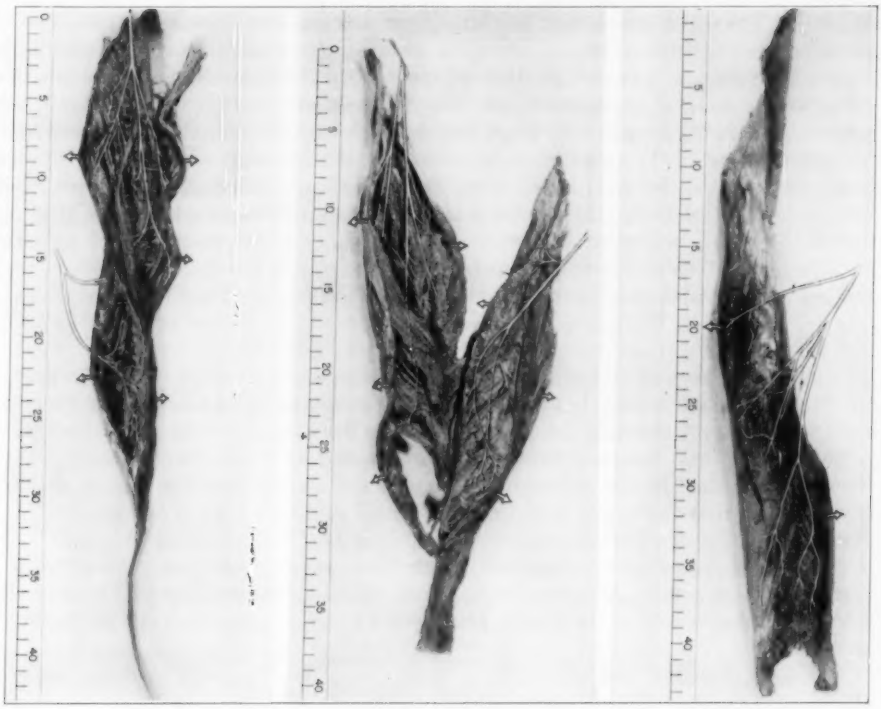

FIG. 10-D
Semitendinosus.

FIG. 10-E
Biceps femoris.

FIG. 10-F
Semimembranosus.

second nerve lies along the medial border of the muscle. At the junction of the upper and middle third, the first branch enters the medial border and divides into two filaments: one filament turns upward a short distance to end among the medial muscle fibers, while the other filament subdivides into three fairly large twigs which run downward and laterally to supply the middle third of the muscle and eventually terminate near the anterior surface of the lower third. The second branch runs farther down the medial border to the lateral third of the muscle, where it divides into two filaments; one of these penetrates anteriorly and laterally as far as the mid-line, and the second descends into the substance of the muscle along its medial edge as far as the quadriceps tendon to supply the lower medial quarter of the rectus femoris.

Variations

Rarely a tendon of origin may arise, not from the anterior inferior spine of the ilium, but from the anterior superior spine. Occasionally, the deep or reflected head of origin may be absent. An accessory head of origin sometimes arises from the rim of the acetabulum and inserts into the ventral margin of the vastus lateralis. These minor variations usually are innervated by branches of the nerves which are distributed to the rectus femoris.

Sartorius

Morphology

The sartorius arises from the anterior superior spine of the ilium and from the adjacent bone. It inserts into the medial surface of the tibia at or near the tuberosity, and also into the neighboring fascia of the leg. The muscle fascicles run a nearly parallel

course. The most proximal ones originate by short tendinous strands, some of which terminate irregularly into the connective tissue at the point where the sartorius approaches the adductor longus. Lockhart and Brandt reported that by dissection of the adult human sartorius they isolated fibers which were thirty-four centimeters in length. In this investigation fibers approaching that length were not found, but instead, many fibers were traced from their origin to the point where the sartorius, the rectus femoris, and the adductor longus approach each other. Many other fibers which originated at approximately that level were traced distally. The muscle is inserted by an aponeurotic layer into the upper part of the medial surface of the shaft of the tibia, above and in front of the insertions of the gracilis and the semitendinosus, and, by its borders, into the fascial expansions which join the capsule and the medial collateral ligament of the knee joint and the fascia of the leg.

Nerve Supply

The nerve to the sartorius (Figs. 7 and 10-A) usually is single, but soon divides into five branches which supply that muscle. Frequently an additional branch from the saphenous nerve passes through the sartorius and is distributed cutaneously. The muscle branches arise from the main nerve in succession and all enter the deep surface of the muscle, where they lie just within its substance. The *highest branch* enters the middle of the upper third at the muscle near its mid-line and continues toward its lateral edge. Its filaments turn both superiorly and inferiorly, supplying the upper lateral quarter of the sartorius. The *second branch* enters only slightly distal to the first, and divides into two filaments which supply the upper medial third of the sartorius. The *third branch* enters near the medial border of the muscle at the junction of its upper and middle thirds; one short filament runs anteriorly into the substance of the muscle and a second, larger, filament passes distalward almost to the muscle tendon. This descending filament supplies the upper medial two thirds of the sartorius. The *fourth branch* enters the deep surface somewhat lateral to the mid-line. Within the substance of the muscle, the nerve divides into two filaments. The more medial courses distalward through the substance of the muscle near the mid-line almost to the tendon; the lateral filament divides into three twigs, one running cephalad and one caudad near the lateral border; the third runs parallel to the second but a little medial to it. The *fifth branch* divides before entering the muscle: its medial filament enters at the junction of the middle and lower thirds, where it lies between the descending filaments of the third and the medial filament of the fourth branches. Coursing downward, the nerve terminates near the muscle tendon. The lateral filament of the fifth branch enters the lateral side of the deep surface of the sartorius in its lower quarter, and divides into two long twigs which descend parallel to one another.

Gracilis

Morphology

The gracilis is morphologically a long, flat, tapering muscle placed on the medial side of the thigh and superficial throughout its length. It arises by a short, thin, and wide tendon from the lower half of the edge of the pubic symphysis and adjacent pubic arch. It is inserted into the upper part of the medial surface of the shaft of the tibia between the sartorius and the semitendinosus.

Nerve Supply

The nerve to the gracilis (Figs. 9 and 10-C) is usually the terminal branch of the anterior division of the obturator nerve, and lies deep to the pectineus and adductor longus and anterior to the adductor brevis and adductor magnus. At or near the medial border of the adductor longus, it divides into a medial and lateral branch, each of which divides into several filaments before entering the posterior surface of the muscle belly. The uppermost filament of the *lateral branch* enters the muscle near its mid-line, about the middle of its

upper third, and gives off small ascending and descending fibers to the upper lateral border of the muscle. The two remaining filaments of the lateral branch enter the muscle near the junction of its upper and middle thirds and continue distalward, parallel to the lateral border of the muscle. The *medial branch* of the nerve to the gracilis likewise breaks up into three filaments, which supply the upper medial portion of the muscle. The two lateral filaments of the medial branch enter the muscle at the junction of the upper and middle thirds and run distalward between and parallel to the muscle fibers, to supply the medial border of the muscle. These terminate near the tendinous portion of the muscle.

Variations

Occasionally the muscle is divided into two parts. The anomalous second portion may attach to the fascia lata or to the medial intermuscular septum.

The tibial nerve to the adductor magnus (Fig. 6, *a* and *b*) usually arises cephalad to those branches of the sciatic nerve which supply the hamstring muscles. The nerve immediately divides into three branches which pass into the clefts of the muscle and are distributed to the various fascicles of its posterior portion.

FUNCTIONAL STUDIES IN THE DOG

Methods and Procedures Used in Studying Movement

The dogs were anaesthetized and either subjected to spinal transection or prepared for cortical stimulation. The behavior of the muscles or parts of muscles was studied in the following ways.

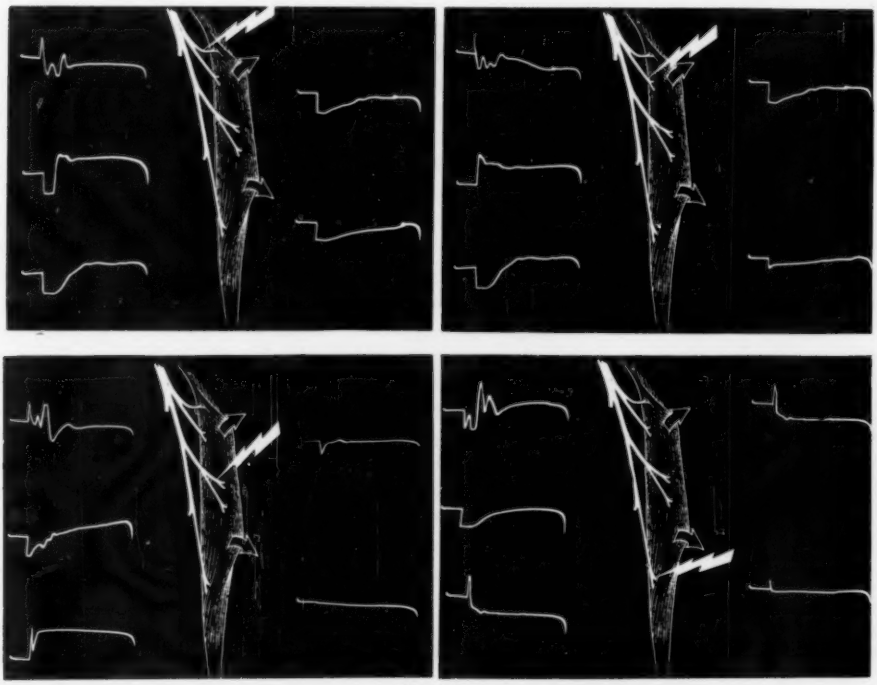

FIG. 11

Illustrating the action potential recorded from the muscle when one branch is stimulated at a time. Stimulation of a single branch is followed by an action potential only in that area of the muscle supplied by that branch.

1. The muscles were always completely exposed and some information was always acquired by palpation and inspection of the muscles which were being stimulated.

2. The muscle potential was visualized on the screen of a cathode-ray oscilloscope. Photographic records were made of the electrical activity in areas which were shortening, being stretched, or contracting isometrically.

3. The amount of change in length, either shortening or lengthening, was recorded photographically. Markers were placed on the muscles to serve as points of reference.

4. Work curves were determined for some of these muscles.

5. Length-tension curves were established for some of the muscles.

These various techniques were often combined to obtain different kinds of data on the same muscle and on the same functional area of that muscle.

Activity of Muscles during Movement of the Hip Joints and Knee Joints

We have previously demonstrated [3,4] that electrical stimulation of branches to isolated areas of a muscle produces isolated contraction, and that shortening of one segmental area of the muscle may occur with concomitant stretching of another area. For example, the nerve which supplies the sartorius of the dog divides into four branches as it approaches the muscle. Stimulation of any one of these four branches causes contraction of only one of the four areas of the muscle. The boundaries of areas which contract separately were outlined by markers placed on the surface and by recording of the electrical potential which arises from the four parts of this muscle. Stimulation of one nerve branch produces an electrical potential only in the area of the muscle supplied by that branch (Fig. 11). This generalization is true for the muscles described above: the semitendinosus, the biceps femoris, the gracilis, and the sartorius of the dog.

To illustrate further the actions of these muscles, the behavior of the various parts of the muscles was studied during reflex activity and during cortical stimulation.

The *semitendinosus* is physiologically a digastric muscle. During reflex activity, or during cortical stimulation, that portion of the muscle proximal to the tendinous inscription shortens during extension of the hip; the portion distal to the inscription shortens during flexion of the knee; and both portions shorten when there is simultaneous extension of the hip and flexion of the knee. During simultaneous flexion of the hip and knee, the proximal portion of this muscle stretches while the distal part shortens. During simultaneous extension of the hip and knee, the proximal part of the muscle shortens and the distal part elongates. Under these five combinations of movements an action potential occurs in both parts of the muscle—in the part which shortens and in the part which is being stretched. Thus one part of the muscle is contracting concentrically and the other part eccentrically.

The two parts of the semitendinosus function as though they were reciprocally innervated. These two parts may be regarded as a flexor and an extensor muscle attached to an intervening inscription. The length of each part of this muscle adapts itself to the position of the two joints: the proximal part shortens or lengthens as the hip is moved; the distal part shortens or lengthens as the knee is moved. The long muscle fibers of the two portions are connected end to end through the tendinous inscription and are able to exert force through almost the full range of movement, from combined hip flexion and knee extension to hip extension and knee flexion.

The force exerted to extend the hip joint or to flex the knee joint is determined by the length of the two parts of the muscle. Hence, the proximal part of the muscle can act as a powerful extensor at the hip joint when that joint is in a position of flexion, irrespective of whether the knee joint is flexed or extended. Likewise, the distal part of the muscle can act as a powerful flexor at the knee joint when the hip joint is either flexed or extended. Obviously, in this muscle as in any simple muscle, the ability of the two parts to develop tension decreases markedly as the muscle fibers of that part approach minimal length.

Denervation of either the proximal or the distal portion of this muscle renders that part incapable of acting on the adjacent joint. In addition, the denervated area stretches and allows the inscription to shift as far as the fascial attachment will allow, thereby decreasing the efficiency of the other portion of the muscle. In the dog, the fascial attachment shifts enough to decrease the effectiveness of the still innervated portion, but not enough to render it incapable of producing movement at one joint,—that is, after the nerve to the proximal portion of the muscle has been sectioned, the distal portion can still flex the knee joint, because the fascial attachment restricts the stretching of the proximal portion. Likewise, denervation of that part distal to the inscription decreases the effectiveness of the proximal portion as a hip extensor, but hip extension can be carried out by contraction of the still innervated portion of the muscle.

The *semimembranosus* in the dog is described as a single muscle only because it is enclosed within a single sheath. It is morphologically two units, in that it has two insertions and is innervated by two nerves. It acts as two parallel units with separate functions. That portion which inserts above the knee shortens during extension at the hip, when extension is induced reflexly, either by crossed extension or by cortical stimulation; that portion which inserts below the knee shortens during reflex withdrawal or cortically induced flexion of the knee and during extension of the hip.

In the dog, the two parts of the semimembranosus lengthen under the following conditions: The flexor portion lengthens when the knee is being extended and the hip is being flexed,—that is, during crossed extension and during flexion of the hip induced by cortical stimulation. The extensor portion lengthens during an ipsilateral withdrawal reflex and also during flexion of the hip induced by cortical stimulation. Both portions of the muscle shorten during those movements which involve simultaneous extension of the hip joint and flexion of the knee joint.

The *biceps femoris* acts as two parallel muscles. In the dog, one portion of the biceps inserts below the knee and the other portion, which in general is comparable to the long head of the biceps in the human, is inserted onto the femur. Therefore, in the dog, this portion of the biceps is not influenced by movement of the knee; it serves only as a hip extensor. It relaxes during reflex withdrawal, when the other portion of the muscle is shortening to flex the knee. In the dog, these attachments and the manner of innervation enable the extensor portion to extend the hip without tending to influence the position of the knee.

In the dog, the flexor portion of the biceps, arising from the ischial tuberosity, must always tend to extend the hip when it flexes the knee. In the human, the situation is different. As is well known, the flexor part of the biceps (the short head) can flex the knee without extending the hip. In the dog, as in the human, these two parts of the muscle may be used simultaneously when there is simultaneous extension of the hip and flexion of the knee.

The semimembranosus, because of the shortness of its fibers, shortens relatively little, but because of the large number of fibers, or great physiological cross section, it acts powerfully during this short range of contraction. In the dog, because all of the muscle arises from the ischial tuberosity, its length is modified by the position of the hip joint, which, in turn, influences the range through which the muscle acts as a powerful flexor of the knee. If the thigh is at a right angle to the body, this muscle acts as a powerful knee flexor during the time when the knee joint is being moved through its range of movement from 115 to 90 degrees.

The sartorius of the dog is composed of two parts: the medial part, which shortens reflexly during flexion, and the lateral or anterior part, which shortens both during reflex hip flexion and knee extension. The lateral portion of the muscle resembles the rectus femoris of the human. The two parts of this muscle in the dog behave differently during the two movements of the joints, that is, flexion of the hip joint and extension of the knee

joint. The proximal part of the lateral portion of the sartorius (upper two areas in Figure 11) shortens during hip flexion. The distal part (lower right area) shortens during reflex extension of the knee. The central part (lower left area) participates actively in both reflexes and appears to be of greatest importance during simultaneous flexion of the hip and extension of the knee.

The *rectus femoris* of the dog is composed of two parts. The superficial part of the muscle continues toward the quadriceps tendon and shortens during extension at the knee and flexion at the hip joints. The deeper, somewhat enclosed, portion arises largely from the reflected head and passes laterally to insert through the fascia lata on the lateral intermuscular septum. This portion of the muscle shortens during reflex flexion of the hip, or when flexion of the hip is induced by cortical stimulation. These two parts of the muscle lengthen under the following conditions: When the knee is being flexed, the more superficial portion of the muscle lengthens even though the hip may be in the process of flexion at that time; in a somewhat comparable manner, the deeper portion of the muscle lengthens when the hip is being extended, quite independently of whether the knee is being flexed or extended. Both portions of this muscle shorten when there is simultaneous flexion of the hip and extension of the knee, and both portions of this muscle lengthen when there is simultaneous extension of the hip and flexion of the knee.

The *gracilis muscle* of the dog is primarily an adductor of the thigh and leg. It also participates in two reflex movements. The rounded distal portion shortens during flexion at the knee and at the hip which is induced either by ipsilateral reflex withdrawal of the limb or by cortical stimulation. The flatter, more proximal, and more anterior portion shortens during flexion at the hip, but not during flexion at the knee which is induced by cortical stimulation. Neither portion contributes much to the strength of flexion at the hip.

DISCUSSION

Movement at two joints can be produced simultaneously by all of the muscles of the thigh which pass over two joints. Simultaneous flexion at the hip and knee can be caused by the sartorius and the gracilis; simultaneous flexion at the hip and extension at the knee by the rectus femoris; and simultaneous extension at the hip and flexion at the knee by the semitendinosus, the semimembranosus, and the biceps. It may be of academic interest to note that there are four possible combinations of simultaneous movements at the hip and knee (Fig. 1) and that three of these possible combinations can be produced by muscles which pass over two joints. There is no muscle which can produce the fourth combination of movements, — that is, simultaneous extension at the hip and at the knee. This combination occurs when the body weight is raised from a chair or from one stair step to the step above and would seem to be as important as the combined flexion at knee and hip which occurs during a withdrawal reflex or when the foot is raised over an obstacle.

Movement at one joint only can be produced by all of the thigh muscles in the dog. The statements in standard textbooks would indicate that, in the human, the muscles which act over two joints in the thigh must produce motion at both the hip and the knee joints, unless other muscles are brought into play to prevent movement at one joint. In the dog, each of these muscles, that is, the semitendinosus, the semimembranosus, the biceps femoris, the rectus femoris, the gracilis, and the sartorius, is capable of producing movement at one joint only. Moreover, these muscles are capable of producing movement at one joint without offering resistance to the antagonistic movement of the other joint. Our morphological studies indicate that this may also be true in the human. The nerve branchings to these muscles, in the human, suggest that one portion of each muscle may shorten while another portion lengthens. In the dog, activity is carried out without dissipation of energy on the prevention of an undesired movement. It seems difficult to believe that the pattern of attachment and the pattern of innervation of the various parts of the muscle are not evidence that the same pattern of behavior is followed in the human. It seems

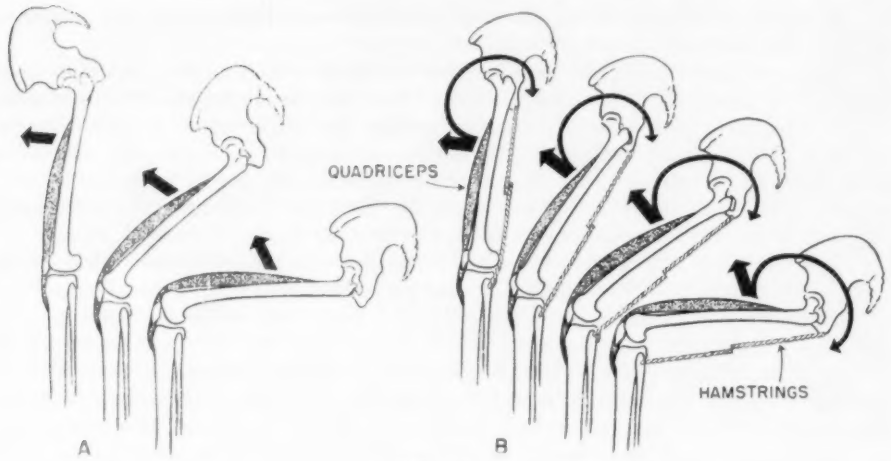

FIG. 12

A illustrates the participation of the quadriceps femoris in extension of the knee joint, as in rising from a chair.

B illustrates that, by means of a force couple, the hamstrings may, by acting as a rope, transmit tension developed by the quadriceps and extend the hip joint through about half the range of movement. During this part of the act of rising, the hamstrings need not shorten. During the remainder of the range of movement, the hamstrings must shorten to extend the hip joint.

very probable that in the human, the portion of each of these muscles which will produce the desired movement actually shortens and that the portion which would not produce the desired movement, or would have a tendency to prevent it, does not contract.

Fascial attachments play an important role in transmitting the force of three of the muscles of the thigh: the semitendinosus, the rectus femoris, and the sartorius. Because of these fascial attachments, these three muscles may produce their action on the hip joint quite independently of movement at the knee joint. This generalization must apply to the human as well as to the dog. Because of their fascial attachments, these three thigh muscles can act on the hip joint without necessitating the antagonistic action of another muscle. Likewise, because of its fascial attachments, the distal portion of the sartorius and of the semitendinosus may act on the knee joint without extending the hip joint. In the

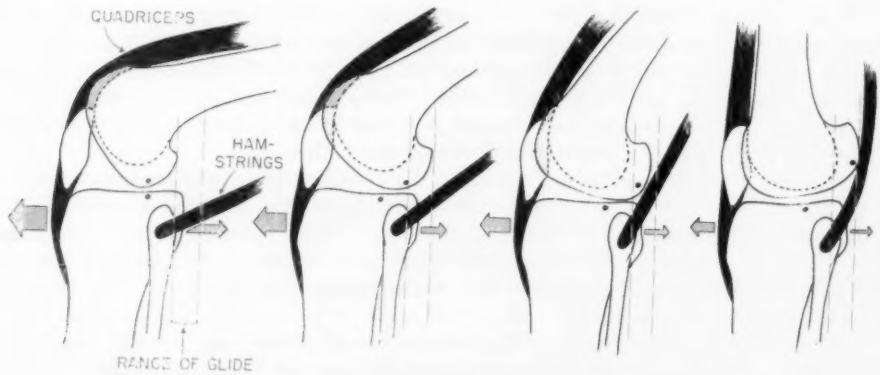

FIG. 13

Illustrating how the quadriceps femoris and the hamstrings influence the gliding of the femur over the tibia during extension of the knee. The dots on these two bones may serve as points of reference in connection with the forward roll of the femur. The backward glide is indicated by the bracketed lines.

dog, these actions may be carried out under circumstances which involve lengthening of the proximal portion of these two muscles.

Reciprocal innervation plays an important role in the control of the thigh muscles of the dog. The separately functioning portions of these muscles are reciprocally innervated, but not necessarily with another portion of the same muscle. Instead, reciprocal innervation is of the type which involves activity of the muscles acting on the opposite side of the joint concerned. Thus the proximal portion of the semitendinosus is reciprocally innervated in relation to the flexors of the thigh; the distal portion of the semitendinosus is reciprocally innervated in relation to the extensors of the knee.

The *relation of fiber length to range of action* deserves some comment. Most of the authors of standard works on human anatomy comment on the relatively short length of the fibers in those muscles which act over two joints, and conclude that these muscles cannot act through the complete range of movement of both the knee and the hip joints. This conclusion ignores the fascial attachments of the semitendinosus, the rectus femoris, and the sartorius. These fascial attachments undoubtedly explain the observation that the muscles under discussion are still taut even when the knee joint has been moved through a range which theoretically would have taken up the available shortening if all of the attachment extended beyond the knee. Because of the fascial attachments in the human, it should be stated that those fibers which pull on the fascia of the thigh may act through their full range of movement irrespective of the position of the knee. Only those fibers which do not pull on the fascia are incapable of moving the hip joint when the knee is in certain positions.

An *elastic mechanism* is said to be involved in some of the actions of muscles which act over two joints. For example, when the knee is completely flexed, the stretched rectus femoris tends to flex the hip unless other muscles prevent this movement; when the hip is fully extended by the hamstrings, the rectus femoris similarly tends to extend the knee. Thus the hamstrings bring about tensions which tend to oppose, or at least limit, the actions which they themselves produce, that is, they generate in the opposing muscles a resistance to the actions which they produce. This arrangement is said to provide a balanced elastic mechanism to facilitate a combination of extension of the hip with extension of the knee, and flexion of the hip with flexion of the knee, as is desirable in walking. This concept is truly a tempting one, but it must be questioned because of the following facts.

The elastic, or resting, tension of the rectus femoris is increased only when the knee is fully flexed and the hip is fully extended. However, neither joint is moved through its full range in walking. Because the conditions of extreme movement of the hip and knee joints which would increase the elastic (resting) tension never occur during walking, it is inconceivable that this so-called elastic mechanism is ever involved in walking. The muscle-tension curves in published reports demonstrate that the resting tension of the muscles does not begin to rise prior to the last few fractions of *in situ* elongation of a muscle.

Instead of attempting to postulate an elastic mechanism in walking, it seems more reasonable to postulate an eccentric contraction of muscle.

Eccentric contraction plays an important role in the activity of those muscles of the thigh which act over two joints. When the knee is flexed, a part of the rectus femoris is stretched. This stretching of the rectus femoris may initiate reflex stimulation and cause contraction of enough muscle fibers to bring about eccentric contraction of the rectus femoris. This stretching of the rectus femoris does occur when the flexion of the knee is only as great as during walking.

When the rectus femoris of the dog was elongated by cortically induced contraction of the hamstrings, sensory impulses were recorded electrically from the peripheral part of the cut nerve to the rectus femoris. Sensory impulses were also recorded from the cut nerves to the vastus lateralis and vastus medialis when the knee was being flexed by cortically induced contraction of the hamstrings; similar electrical impulses were recorded

from the cut nerves to the iliopsoas during extension of the hip. Obviously, the spinal cord receives proprioceptive stimuli arising from muscles which are elongated by movement of the hip, or the knee, or both simultaneously. The proprioceptive stimuli initiated by stretching of that part of the rectus femoris which passes over both the hip and the knee is influenced by the relative position of the two joints. Proprioceptive stimuli caused by stretching those muscles which act over both the hip and knee may initiate an eccentric contraction which in turn may facilitate a well coordinated combination of extension of the hip with flexion of the knee, as is desirable in walking.

Specific muscles for specific actions were not identified under conditions of maximal stimulation. Each of the two-joint muscles of the thigh can cause movement only at either the knee or the hip, only when moderately strong movement is required and each is, in that sense, a specific muscle for a single joint. They are not specific for a single joint under conditions which require maximal strength of movement. In the dog, it was demonstrated that the starting position of the hip or the knee joint determines which muscle contributes most to movement away from the starting position. Even when the joints are passively placed in a position which shortens some muscle fibers beyond their minimal effective length, an action potential occurs.

When movement is of moderate strength, only those muscles or parts of muscles which act on a single joint are activated. However, when the strength of movement is maximal, all of the fibers which can cause movement at that joint contract. Under conditions of maximal strength of movement, a second joint is moved unless antagonists act at the second joint.

Force couples constitute one of the activities of muscles which act over two joints. These muscles are ideally arranged to participate in certain kinds of force couples. It was demonstrated that, during an extensor reflex, the quadriceps femoris contributes to the forcefulness of extension at the hip joint, — that is, when the limb is in a weight-bearing position, extension at the hip joint is weakened when the quadriceps is either denervated or detached from its insertion.

The action can be compared to the attempt of the human to rise from a chair. The force exerted by the quadriceps extends the knee joint (Fig. 12,*A*). That portion of the hamstrings which bridges both the hip and the knee joints contracts isometrically or eccentrically throughout the first half of the range of movement (Fig. 12,*B*). Consequently, the force originated by the quadriceps is transmitted by the hamstrings to the hip joint and causes extension of the hip joint even though the hamstrings are not shortening. Our studies of the amount of movement of the tendons of the hamstrings during flexion of the knee do not unequivocally answer the question of whether isometric contraction of the hamstrings can explain the first half of this movement. Only during the last half of this movement need the hamstrings shorten appreciably to produce extension of the hip. Perhaps one of the functions of muscles acting over both the hip and the knee joints is participation in force couples.

Stabilization of joints may be one of the functions of two-joint muscles. As is well known, during extension of the knee the femoral condyles roll forward and glide backward on the superior articular surfaces of the tibia. It appears probable that, when a person rises from a chair, two forces influence the tendency of the femur to glide over the surface of the tibia. The force exerted over the distal end of the femur drives it backward over the surface of the tibia (Fig. 13). This tendency to glide is counteracted by the force of the hamstrings which tend to pull the femur forward over the surface of the tibia. Prevention of excessive gliding at the knee joint during simultaneous extension at the hip and the knee apparently is one of the important functions of those muscles *which act over these two joints.*

SUMMARY

Evidence from functional studies in the dog and morphological studies in the human

suggests that all of the muscles of the human thigh can, by contraction, produce tension at one joint only. The evidence presented also indicates that movement at the hip without movement at the knee can be produced by a part of the rectus femoris, the sartorius, the gracilis, the semitendinosus, the semimembranosus, and the biceps femoris; and that movement at the knee without movement at the hip can be produced by the gracilis and the biceps femoris.

Whereas most of the tension resulting in movement at two joints is transmitted by tendons to attachments to bone, most of the tension resulting in movement at a single joint is transmitted to fascia.

Eccentric contraction of the parts of these muscles which act over two joints may facilitate coordinated, simultaneous movements at both the hip and the knee.

The muscles which act over two joints are ideally arranged to participate in certain kinds of force couples. When the body weight is raised from a chair, some of the tension produced by the quadriceps femoris can be used by the hamstrings to extend the hip joint, even when the hamstrings are not shortening.

Prevention of excessive gliding at the knee joint appears to be one function of two-joint muscles.

REFERENCES

1. Hollinshead, W. H., and Markee, J. E.: The Multiple Innervation of Limb Muscles in Man. J. Bone and Joint Surg., **28:** 721–731, Oct. 1946.
2. Lockhart, R. D., and Brandt, W.: Length of striated muscle-fibers. (Abstract.) J. Anat., **72:** 470, 1938.
3. Markee, J. E., and Löwenbock, Hans: The Relations between Multiple Innervation and "Segmental" Response of Skeletal Muscle of the Dog. J. Neurophysiol., **8:** 409–420, 1945.
4. Markee, J. E., and Williams, Maude: The separate contraction of functional areas in limb muscles during reflex withdrawal and crossed extension. Fed. Proc., **7:** 78, 1948.

DISCUSSION

Dr. W. M. Phelps, Baltimore, Maryland: I should like to discuss Dr. Markee's paper with regard to the two-joint function of the muscles which he has described. I have always wanted to determine why tight hamstrings sometimes cause flexion of the knee and at other times do not; this has interested me especially in regard to spastic patients. The straight-leg-raising test used to test tight hamstrings is usually done with the patient's knee held perfectly straight; there is no contracture at the knee, and yet we call these hamstrings "tight".

In other instances, especially in spastic patients, we find that there is considerable knee-flexion contracture, which we also ascribe to tight hamstrings. This has always been rather confusing and we felt that some answer should be worked out.

For years we have been injecting muscle bellies rather than nerves with novocain, to determine whether individual muscles are spastic or show contracture. When the muscle belly in a spastic muscle is injected with novocain, the spasticity disappears for a period of twenty to thirty minutes, so that it is easy to tell whether the muscle has a contracture or not. This test has been used for years and is very helpful in determining the procedures which should be carried out to obtain correction. We have found, as did Dr. Markee, that in the case of the semitendinosus the reaction depends upon where the muscle belly is injected. We have been able to place our injections very high in the muscle belly, above the gluteal fold, and find that we can then eliminate the spasticity of the hip-extensor function of the hamstrings. However, if we inject this same muscle far down, in the lower part of the muscle belly, we can eliminate the spasticity of the knee-flexion component. This is merely a test which we have used to determine whether the spasticity is affecting the hip-extensor function of the semitendinosus or the knee-flexor function. This, I think, bears out Dr. Markee's clinical observation.

Dr. William Green, Boston, Massachusetts: If I may comment briefly on Dr. Markee's paper, I think he has given us graphic evidence that the Lord really had very good plans for the construction of human beings and other animals. Since some muscles run across two joints, it would certainly be impractical to stabilize each joint with other muscles, so that one muscle can work locally at one joint. As Dr. Markee has pointed out, that is not what takes place. The fact that a particular muscle covers a wide expanse and crosses the two joints does not indicate that the muscle necessarily contracts as a single unit. Particular portions of such a muscle with its special attachments and integrations may work as a unit in carrying out particular functions. That is what Dr. Markee has demonstrated so well.

STUDIES OF BONE METABOLISM

I. A Comparison of the Metabolism of Strontium ^{90} in Living and Dead Bone *

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INTRODUCTION

The purpose of the following experiments was to compare the metabolism of radio-active strontium (Sr^{90}) in dead bone with that in living bone. It was felt that such a study would help to explain the roentgenographic changes observed in aseptic necrosis, to elucidate the mechanisms involved when bone-seeking radio-active elements, such as radium, fail to respond to treatment effective for mobilization of stable isotopes[1], and, further, to clarify the role played by the bone cells in inorganic salt metabolism.

Clinically, avascular or aseptic necrosis may occur as the result of trauma, chemical poisoning (for example, phosphorus), emboli (for example, caisson disease), or as a result of radiation. In addition, there are instances of aseptic necrosis, such as epiphysitis of growth centers and osteochondritis dissecans, in which the specific causes are unknown but which are probably related to interruption of the blood supply. The diagnosis of aseptic necrosis is usually based on an apparent increase in density, seen roentgenographically, of the involved area of bone. With revascularization, areas of decreased density appear on the roentgenogram, which may erroneously be interpreted as "fragmentation".[9]

Various interpretations have been placed on the roentgenographic changes in density observed in aseptic necrosis. Phemister postulated that the necrotic bone is of the same density as normal bone, the appearance of increased density being due to an actual decrease in the density of the adjacent living bone. Brailsford, on the other hand, suggested that the necrotic fragment, although deprived of blood supply, may acquire additional calcium from the surrounding tissue fluids and that the increase in density is real rather than relative. Experimental studies have led to contradictory conclusions. Kind, using autografts of bone placed intramuscularly in rabbits, reported that one third of the grafts showed decalcification as early as at the end of the first day, although hypercalcification occurred in two of the grafts which had previously been dried and freed of fat. Perrottet, in a study of bones necrosed *in situ* by heating (80 degrees centigrade for three minutes), found initial hypermineralization on the sixth and fifteenth days, followed by a return to normal on the twenty-first day.

Radio-active isotopes have been used more recently to study the problem. Odell, Mueller, and Key studied the uptake of radio-active phosphorus (P^{32}) in fresh autogenous, boiled, and frozen bone grafts placed intramuscularly in dogs and came to the conclusion that the acquisition of P^{32} by the grafts was the function of the surface area exposed to the solution perfusing the bone. Fresh autogenous grafts picked up five times as much P^{32} as did the boiled grafts and two times as much as did the frozen bone, a difference that these investigators thought was due to a change in the protein structure induced by the physical agents, as well as by the altered access of the perfusing solutions to the surfaces of the bone. Kiehn, Friedell, and MacIntyre carried out similar experiments on dogs, using iliac bone placed subcutaneously. They reported that in the first twenty-four hours the uptake of P^{32} in the fresh grafts was 60 per cent. that of the intact ilium, but after ten days the percentage tended to increase. Boiled grafts showed an uptake of only 7 per cent. Frozen grafts, on the other hand, showed uptakes approximating those of fresh grafts,

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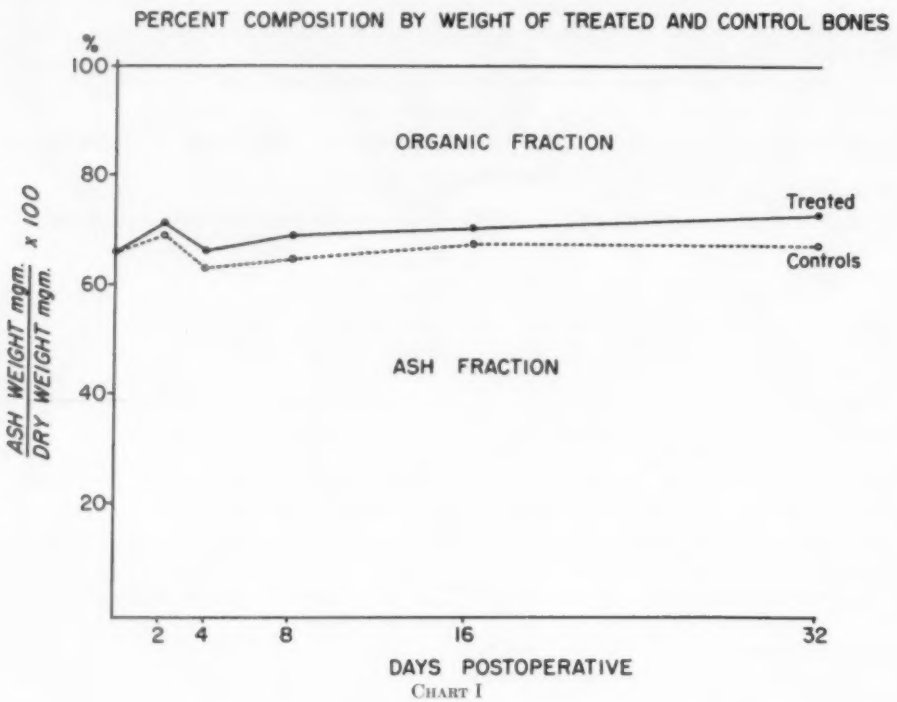

CHART I

following an initial depression. These experiments are interpreted as indicating that cellular viability is not an essential factor in the uptake of inorganic salts by bone matrix. It has even been suggested that cellular activity may inhibit the process of the uptake of inorganic salts by the skeleton. Neuman and his associates[11,12], on the basis of *in vitro* studies with uranium, reported that fresh bone absorbed only 12 per cent. as much uranium as did bone ash.

From the foregoing, it would appear that devitalized bone may acquire inorganic salts from the surrounding tissue fluids, but the corollary, the mobilization of inorganic salts from avascular bone, is less settled. In the following studies, the uptake and mobilization of Sr^{90} by living and dead bone was compared, both *in vivo* and *in vitro*.

IN VIVO STUDIES

Methods and Materials

Grouping of animals: Two groups of Long-Evans female rats between two and three months of age and 220 to 344 grams in weight were used in the following two *in vivo* experiments on Sr^{90} uptake (eleven animals) and Sr^{90} mobilization (fifteen animals).

Uptake: In the first experiment, the right radius was removed, was frozen in liquid carbon dioxide for five minutes, and was thawed for five minutes in isotonic saline at 37 degrees centigrade. The freezing and thawing procedure was carried out three times; then the bone was restored to its original location in the limb. Autopsies were done on subgroups and both radii were removed on the second, fourth, eighth, sixteenth, and thirty-second postoperative days. Each animal had received a single injection of radio-active strontium intraperitoneally twenty-four hours prior to sacrifice. One of the frozen and thawed bones from each subgroup of rats was sectioned for histological study; the others were used for chemical analysis.

Mobilization: In the second experiment, the same procedure was followed, with the

TABLE I

UPTAKE OF Sr^{90} *in Vivo*

Rat	Autopsy		Counts per Minute per Milligram Ash Weight × 10^{-2}		
	Postoperative Days	Postinjection Days	Living Sample	Dead Sample	Ratio of Living to Dead Bone
2682 B	2	1	7.25	5.38	0.74
2080 BH	2	1	6.78	4.96	0.73
2577 GH	2	1	5.26	3.13	0.60
2485 B	4	1	6.01	4.66	0.78
2046 GH	4	1	8.18	5.14	0.63
2413 GH	8	1	7.84	3.83	0.49
2506 BH	8	1	7.50	3.20	0.43
1936 G	16	1	6.26	4.64	0.74
2022 BH	16	1	5.85	4.72	0.81
2392 B	32	1	3.65	3.01	0.82
2284 G	32	1	7.73	5.18	0.67

exception that the injection of radio-active strontium took place before the removal and the treatment of the radius.

Injection of radio-active strontium: The rats in both groups were given a single intraperitoneal injection of 0.25 cubic centimeter of $SrCl_2$ (Sr^{90}) in isotonic saline, the solution containing an activity of approximately 51.6 microcuries per cubic centimeter. A one cubic centimeter tuberculin syringe shielded with lucite was used for the injections.

Analysis of the bone: At autopsy, both right and left radii were removed for chemical analysis and activity determinations. The rest of the carcass was ashed in concentrated nitric acid. The bones were weighed in crucibles, were dried to constant weight at 96 degrees centigrade, were reweighed (dry weight), and were then placed in a muffle furnace for eight hours at 600 degrees centigrade. Following this, the weight of the ash residue

TABLE II

MOBILIZATION OF Sr^{90} *in Vivo*

Rat	Autopsy		Counts per Minute per Milligram Ash Weight × 10^{-2}		
	Postoperative Days	Postinjection Days	Living Sample	Dead Sample	Ratio of Living to Dead Bone
2490 BH	2	3	3.76	3.66	1.03
2453 BH	2	3	0.33	0.47	0.70
1931 G	2	3	4.16	5.33	0.78
2475 G	4	5	5.12	6.87	0.75
2261 GH	4	5	4.85	4.67	1.04
2656 G	4	5	5.13	6.73	0.76
2054 W	8	9	2.24	4.24	0.53
2491 BH	8	9	2.35	3.65	0.64
2440 B	8	9	2.18	3.72	0.59
2252 G	16	17	2.35	3.59	0.65
2481 BH	16	17	1.21	1.65	0.73
2351 BH	16	17	2.03	2.98	0.68
1968 GH	32	33	6.47	9.02	0.72
2234 GH	32	33	1.32	2.19	0.60
2398 G	32	33	1.73	3.25	0.53

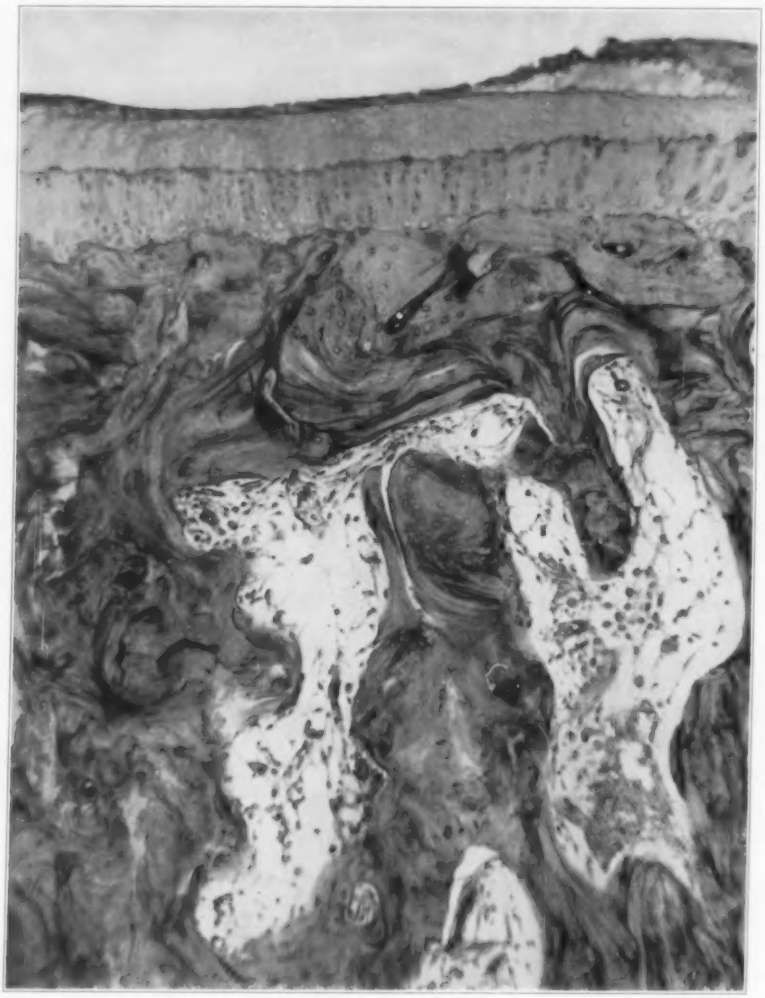

FIG. 1

Photomicrograph (× 80) of a rat radius which had been repeatedly frozen and thawed and then reimplanted for sixteen days shows aseptic necrosis of bone and partial revascularization of the implant.

was determined; the ash was dissolved in 20 per cent. nitric acid, was diluted to volume, and an aliquot was removed for counting.

Determination of activities: The stock solution of Sr^{90}-Y^{90} was prepared by dilution of a carrier-free sample of an equilibrium mixture of the isotopes supplied by Oak Ridge. This solution was calibrated in terms of microcuries per milliliter by comparison with a Sr^{90}-Y^{90} standard having a known disintegration rate. Samples were prepared for counting by mounting an aliquot (10λ to 1000λ) on a two-inch watch glass and by evaporating to dryness. Counting was done with a standard beta-gamma Geiger-Müller counter with a decade scaler. A correction for source size was applied and 1,000 to 5,000 counts were totaled for each sample in order to minimize the statistical error in counting. Since radioactive strontium (Sr^{90}) decays to radio-active yttrium (Y^{90})—sixty-five-hour half-life—

FIG. 2

Photomicrograph (× 160) of the same rat radius as that in Fig. 1 shows cellular detail in the articular cartilage; note the absence of cells in the bone. There was no evidence of new-bone formation either in or adjacent to the implant.

all samples were held for at least fifteen days—five half-lives—before counting, so that equilibrium would be attained.

Histological study: The right radius of one rat from each subgroup was sectioned to determine the effect of repeated freezing and thawing on the bone and to determine what, if any, histological changes occurred following reimplantation. The radius was fixed in Bouin's fluid, was decalcified in versene, was dehydrated, was imbedded in low viscosity nitrocellulose, was sectioned, and was stained with Böhmer's hematoxylin and eosin.

Results

Histological studies: The results of repeated freezing and thawing on the bone are illustrated in Figures 1 and 2, photomicrographs of a radius sixteen days after treatment. The lacunae are uniformly empty, but they retain their shape and show no evidence of

erosion.[18] In contrast, some nuclear detail is present in the chondrocytes and the cellular elements of the periosteum and marrow. There is no evidence of new-bone formation.

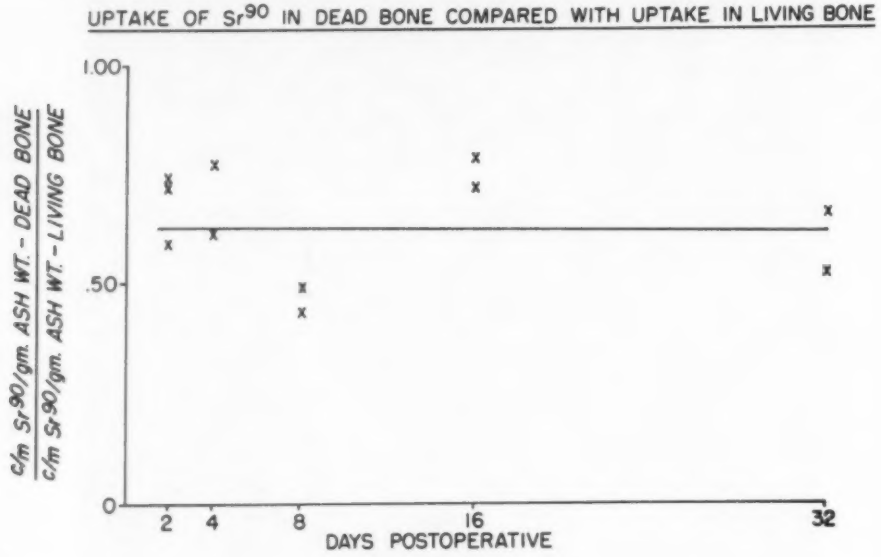

CHART II

One radius was removed, was frozen three times, and was then reimplanted (adult rats). Animals were injected with Sr^{90} twenty-four hours prior to autopsy.

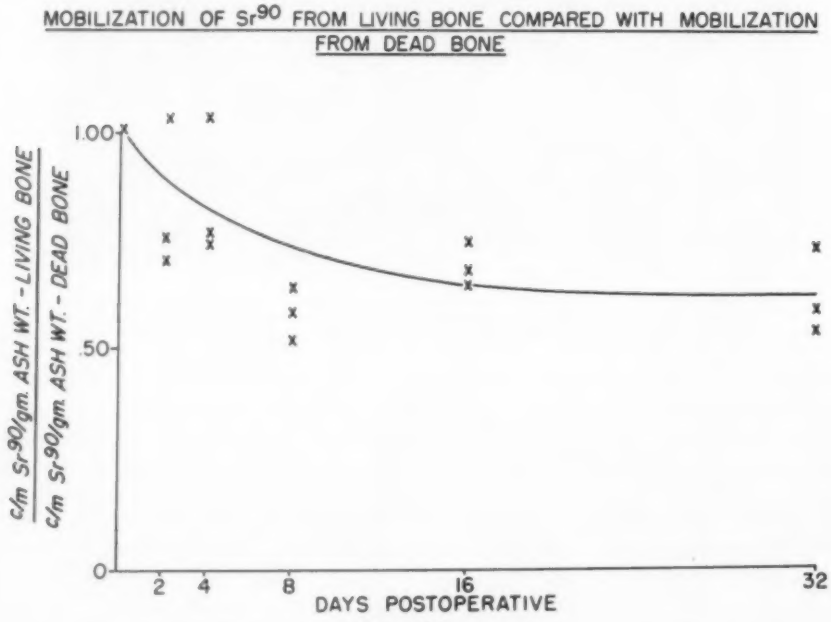

CHART III

Adult rats were injected with Sr^{90}. One radius was removed twenty-four hours later, was frozen three times, and was then reimplanted.

TABLE III

UPTAKE OF Sr^{90} BY BONE IN TWO-DAY TISSUE CULTURES

Rat	Counts per Minute per Milligram Ash Weight $\times 10^{-4}$	
	Living Sample	Dead Sample
A	1.60	1.45
B	1.63	1.71
C	1.88	1.55
D	2.09	1.81
E	1.70	1.57
F	1.78	1.70

Statistical Analysis*	
Living bone:	
Mean	1.78×10^4
Standard deviation	0.17×10^4
Dead bone:	
Mean	1.63×10^4
Standard deviation	0.12×10^4
Standard error of the difference between the means	0.08×10^4
The observed difference between the means is about 1.8 times the standard error of the difference between the two means, that is, the difference is not statistically significant.	

* All figures in statistical analysis are expressed in counts per minute per milligram of ash weight.

From the histological sections, the method of repeated freezing and thawing, following destruction of the blood supply incidental to removal of the bone, is apparently effective in producing aseptic necrosis (confirming Ham's studies).

Chemical studies: There was a loss in actual weight of both the organic component and the ash component of the devitalized bone compared with the intact radius. (The rats were mature and the differences cannot be accounted for by growth of the untreated bone.) The percentage composition of ash (ratio of ash weight to dry weight) was higher in the devitalized radius than in the control bone. Statistical analysis revealed that this difference was significant (P value of less than 0.01). The change was progressive (Chart I).

Uptake of radio-active strontium by devitalized bone: Although the rats in this experiment were all adult animals of stable body weight, there was considerable variation in the actual amount of Sr^{90} deposited in the skeleton (Table I). In order to make comparisons, the ratio of the radio-activity in the devitalized radius to that in the intact bone on the opposite side was calculated (Table I and Chart II), each animal thus serving as its own control. It should be noted that the chart does not depict the uptake of Sr^{90} in terms of increasing time intervals following injection. Injections were made twenty-four hours before autopsy in each case. The devitalized bone showed approximately 70 per cent. as much uptake of Sr^{90} as did the control bone, and there was no apparent difference in the ratio one day after devitalizing the radius and thirty-one days afterwards.

Mobilization of radio-active strontium from devitalized bone: As indicated before, a period of twenty-four hours was allowed to elapse between injection of Sr^{90} and repeated freezing and thawing of the radius in the rats in the second experiment. The counts obtained subsequently in the treated and control bones are given in Table II, and the ratios of the activity in the living to the activity in the dead radius plotted against the post-operative intervals are shown in Chart III. From the chart, it is apparent that, initially, Sr^{90} was mobilized more rapidly from the viable than from the devitalized radius, although an equilibrium was approached at thirty-two days.

FIG. 3

Photomicrograph (× 1100) of a ten-day tissue culture of cancellous rat bone shows the presence of apparently viable cells in the culture. The culture medium contained Sr^{90}.

Discussion

Two factors must be taken into consideration in evaluating the results of these experiments. The first is the effect of repeated freezing and thawing on the bone. Apparently, from the histological sections, this treatment was followed by destruction of the osteocytes and osteoblasts. Necrosis of the cells was probably rapid. However, no conclusions can be drawn from a study of the histological sections concerning the effect of freezing and thawing on the matrix of the bone. The second factor is the effect of surgical removal of the radius and interruption of its blood supply on subsequently altering the surface area

FIG. 4

Photomicrograph (× 1100) of a ten-day tissue culture of bone treated by rapid freezing and thawing shows the absence of cellular elements. The culture medium contained Sr^{90}.

of the bone exposed to active circulation. Some revascularization of the devitalized bone occurred during the thirty-two-day experimental period, but this was far from complete.

Hypermineralization of the devitalized bone was present by the second postoperative day and apparently was slowly progressive during the ensuing thirty days—this in spite of the fact that the dead bone picked up only 70 per cent. as much Sr^{90} as the intact radius. (Hypermineralization represents a balance between deposition and mobilization, whereas the strontium studies represent uptake primarily.)

Interpretation of the results obtained in the second experiment is complicated by

TABLE IV

UPTAKE OF Sr^{90} BY BONE IN NINE-DAY TISSUE CULTURES

Rat	Counts per Minute per Milligram Ash Weight $\times 10^{-6}$		Statistical Analysis*
	Living Sample	Dead Sample	
G	1.00	0.96	Living bone: Mean 1.02×10^6; Standard deviation 0.07×10^6
H	1.00	1.02	Dead bone: Mean 1.01×10^6; Standard deviation 0.03×10^6
I	0.91	1.04	Standard error of the difference between the means 0.03×10^6
J	1.15	1.02	The observed difference between the means is about 0.3 of the standard error of the difference between the two means, that is, the difference is not statistically significant.
K	1.07	1.04	
L	0.99	1.00	

* All figures in statistical analysis are expressed in counts per minute per milligram of ash weight.

the fact that the initial levels of activity in the bone were not determined. Although 60 per cent. as much activity remained in the living as in the dead bone at the end of the experimental period, the changes in the ratio of the amount in living to that in dead bone may represent actual changes in the amounts of Sr^{90} in the living bone, dead bone, or both. The concentration of Sr^{90} in the blood following intraperitoneal injection drops rapidly during the first two days after injection, and then remains at a relatively constant level[3]. One would expect the normal radius, with a greater surface area exposed to the

TABLE V

MOBILIZATION OF Sr^{90} FROM BONE IN TISSUE CULTURES

Rat	Total Per cent. Sr^{90} Remaining in Bone after 239 Hours		Statistical Analysis
	Living Sample	Dead Sample	(Units used: Per cent. Sr^{90})
M	58.3	84.9	Living bone: Mean 60.5; Standard deviation 3.6
N	55.0	79.2	
O	63.0	80.9	Dead bone: Mean 82.0; Standard deviation 1.9
P	58.9	83.3	
Q	62.1	82.6	Standard error of the difference between the means 1.6
R	65.9	81.0	The observed difference between the means is about 13 times the standard error of the difference, that is, the difference is statistically significant.

declining circulating levels of activity, to lose activity more rapidly than the avascular bone. It is possible, however, that the dead bone, losing activity through the slower medium of diffusing fluids, might eventually reach the same equilibrium. On the other hand, it is also possible that little or no change in activity occurred in the avascular bone.

IN VITRO STUDIES

The foregoing studies are subject to a serious criticism: The circulation of the living and dead bone (and hence the surface areas exposed to body fluids) was different. Because of this, it was decided to carry out two parallel studies in tissue cultures in which the surface areas would be the same.

Methods and Materials

Uptake: Two litters of Long-Evans rats twenty-one to twenty-two days old were used, one litter for a two-day tissue-culture experiment and the other for a nine-day tissue-culture experiment. Weights of the animals ranged from thirty-seven to forty-eight grams. The animals were sacrificed and the distal femora and proximal tibiae were dissected free, sterile precautions being used. The bones from the right and left extremities were kept separate. The bones were mounted in tube cultures, as previously described.[19] The tubes containing bone from the left side were immediately supplied with seven milliliters of nutrient medium containing four microcuries of Sr^{90}. The tubes containing bone from the right side were subjected to quick-freezing temperatures in order to kill the bone and then were supplied with the same medium. All tubes were incubated at 37 degrees centigrade, the first experiment running for two days and the second for nine days, the medium being changed on days two, five, and seven. The medium was then removed, and the bone was washed with normal saline. The bone samples were transferred to previously weighed crucibles, were dried, were ashed at 600 degrees centigrade, were weighed, and were transferred quantitatively to ten milliliter volumetric flasks. Aliquots were taken for counting.

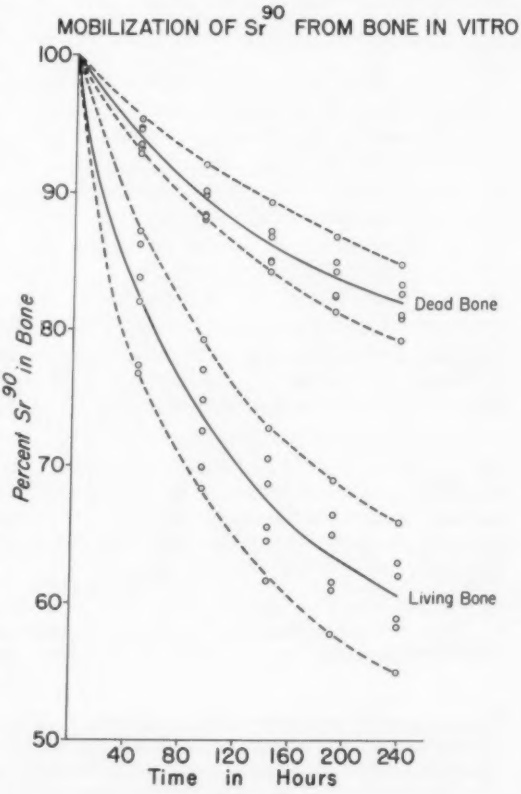

CHART IV

Mobilization: Six twenty-one-day-old Long-Evans rats of the same litter, weighing thirty-eight to forty-two grams, were used. Each received a single intraperitoneal injection of thirty microcuries of Sr^{90} approximately forty hours prior to autopsy. Tissue cultures were prepared at autopsy as in the uptake experiment, with the exception that the medium was non-radio-active. The medium was changed at successive forty-eight-hour intervals over a ten-day period. The solutions were counted for radio-activity at each change of

medium, and at the end of the experimental period (ten days) the activity of Sr^{90} remaining in the bones was determined.

Results

Uptake: The data on the tissue cultures of comparable bone samples, of which one half were living and one half killed by freezing (Figs. 3 and 4) and all of which were maintained for the same period (two days and nine days) in a medium containing Sr^{90}, are summarized in Tables III and IV. All of the samples increased significantly in radioactivity, but there was no significant difference between the ability of dead and living bone to take up Sr^{90} from the culture medium over an exposure period of either two or nine days. The variations observed could have occurred by chance.

Mobilization: In contrast to the results on uptake, there was a definite difference in mobilization of Sr^{90} from dead and living radio-active bone maintained in tissue cultures (Table V and Chart IV). Although slow mobilization occurred from the dead bone, mobilization occurred at a significantly more rapid rate from the living bone.

Discussion and Conclusions

From the foregoing experiments, it is concluded that viability of the bone cells is not essential in the process of inorganic salt uptake by bone, provided the organic matrix is present and normal. The term "uptake", as used in this report, includes several possible processes: ionic exchange, recrystallization, and the formation of new crystals either in the old matrix or in conjunction with the formation of a new matrix. The latter can be demonstrated histologically in living tissue cultures of bone (Fig. 3). However, the amount of matrix formed over a ten-day period is probably insignificant in the over-all process of salt metabolism in tissue cultures, and, of course, need not be considered in the case of the dead bone (Fig. 4). Mobilization of the inorganic salts from bone, on the other hand, is facilitated by the presence of living cells. A corollary of these conclusions is that uptake of radio-active isotopes is probably not an accurate index of bone-cell "viability". This confirms the conclusion previously suggested by the work of Odell and his associates. A second conclusion reached from the present experiment is that the change in radiographic density in aseptic necrosis of bone is probably the result of combined failure of mobilization of inorganic salts and continued uptake by the necrotic bone from the tissue fluids, in addition to the decrease in density of the surrounding viable bone,—that is, the increase in density of the dead bone is actual as well as relative. An interesting sidelight on these observations is that bone-seeking radio-active emitters, such as radium, probably become relatively fixed in the skeleton when radiation damage is sufficient to cause necrosis of the cells.

NOTE: The authors express their deep appreciation to Miss Joan Schmidt for her assistance in the tissue-culture studies.

REFERENCES

1. AUB, J. C.; EVANS, R. D.; GALLAGHER, D. M.; and TIBBETTS, D. M.: Effects of Treatment on Radium and Calcium Metabolism in the Human Body. Ann. Int. Med., **11**: 1443–1463, 1938.
2. BRAILSFORD, J. F.: Osteochondritis. British J. Radiol., **8**: 87–134, 1935.
3. COPP, D. H.: Deposition of Radioactive Materials in Bone. *In* Abstracts, American Chemical Society, 117th Meeting, Detroit, 1950, p. 520.
4. FALKENHEIM, MARLENE; NEUMAN, W. F.; and HODGE, H. C.: Phosphate Exchanges as the Mechanism of Adsorption of the Radioactive Isotope by the Calcified Tissues. J. Biol. Chem., **169**: 713–722, 1947.
5. HAM, A. W.: Some Histophysiological Problems Peculiar to Calcified Tissues. J. Bone and Joint Surg., **34-A**: 701–728, July 1952.
6. JONES, D. C., and COPP, D. H.: The Metabolism of Radioactive Strontium in Adult, Young, and Rachitic Rats. J. Biol. Chem., **189**: 509–514, 1951.
7. KIEHN, C. L.; FRIEDELL, H. L.; and MACINTYRE, W. J.: Study of the Vitality of Tissue Transplants by Means of Radioactive Phosphorus. Plast. and Reconstruct. Surg., **3**: 335–339, 1948.

8. KIND, HANS: Studien zur Frage der Osteolyse. Histologische und chemische Untersuchungen an experimentallen Frakturen und Transplantaten. Beitr. z. Path. Anat., **111:** 283–294, 1951.
9. LUCK, V. J.: Bone and Joint Diseases. Chap. IV. Springfield, Illinois, Charles C. Thomas, 1950.
10. NEUMAN, W. F., and MULRYAN, B. J.: The Surface Chemistry of Bone. VI. Recrystallization in Vivo. J. Biol. Chem., **195:** 843–848, 1952.
11. NEUMAN, W. F.; NEUMAN, M. W.; MAIN, E. R.; and MULRYAN, B. J.: The Deposition of Uranium in Bone. IV. Adsorption Studies in Vitro. J. Biol. Chem., **179:** 325–333, 1949.
12. NEUMAN, W. F.; NEUMAN, M. W.; MAIN, E. R.; and MULRYAN, B. J.: The Deposition of Uranium in Bone. V. Ion Exchange Studies. J. Biol. Chem., **179:** 335–348, 1949.
13. NEUMAN, W. F., and NEUMAN, M. W.: The Nature of the Mineral Phase of Bone. Chem. Rev., **53:** 1–45, 1953.
14. NEWMAN, W. F., and RILEY, R. F.: The Uptake of Radioactive Phosphorus by the Calcified Tissue of Normal and Choline Deficient Rats. J. Biol. Chem., **168:** 545–554, 1947.
15. ODELL, R. T.; MUELLER, C. B.; and KEY, J. A.: Effect on Bone Grafts of Radio-Active Isotopes of Phosphorus. J. Bone and Joint Surg., **33-A:** 324–332, Apr. 1951.
16. PERROTTET, E.: Quoted by Rutishauser and Majno.[18]
17. PHEMISTER, D. B.: Lesions of Bones and Joints Arising from Interruption of the Circulation. J. Mt. Sinai Hosp., **15:** 55–63, 1948.
18. RUTISHAUSER, ERWIN, and MAJNO, GUIDO: Physiopathology of Bone Tissue. The Osteocytes and Fundamental Substance. Bull. Hosp. Joint Dis., **12:** 469–490, 1951.
19. RAY, R. D.; MOSIMAN, ROSCOE; and SCHMIDT, JOAN: Tissue-Culture Studies of Bone. J. Bone and Joint Surg., **36-A:** 1147–1165, Dec. 1954.

DISCUSSION

EXPERIENCES WITH THE PALMER OPEN REDUCTION OF FRACTURES OF THE CALCANEUS

(Continued from page 106)

4. The immobilization may be too long in some cases. This results in a painful, "frozen" foot, similar to the frozen shoulders we commonly see. Those of us who are old enough to remember when fractures of the hip were treated by double hip spicas will remember the stiff knee joints which resulted from the long immobilization.

Dr. Vernon Luck has coined the word "arthrofibrosis" to denote a type of joint reaction characterized by pannus formation from the synovial membrane. This pannus carries chondroclastic cells which destroy the articular cartilage, leading to fibrous ankylosis. A significant etiological factor in the development of arthrofibrosis is severe joint injury, and a second factor is disuse. If the two are combined, we are certainly inviting fibrous ankylosis. He has further shown by animal experimentation that early mobilization tends to prevent arthrofibrosis. Therefore, we have been decreasing the duration of plaster immobilization following surgery, recently to as short a period as four weeks. As soon as the cast has been removed, the patients begin a vigorous program of foot exercises for five minutes out of every hour, much the same as the quadriceps exercises commonly used following knee injury. Weight-bearing is not allowed for twelve weeks.

With these modifications in Dr. Palmer's original technique, particularly in the postoperative care, we are as enthusiastic as Dr. Maxfield is about the method.

DR. ROBERT LEE PATTERSON, NEW YORK, N. Y.: I would like to compliment Dr. Maxfield and Dr. McDermott on a fine presentation. Two points in Dr. Maxfield's technique are well worthy of note for those who are performing open replacement of the depressed articular surfaces: first, the temporary use of the Steinmann pin or Kirschner wire through the posterior fragment in order to control the talocalcaneal joint at the time of operation, and, second, the use of bone other than from the local area to fill in the space from which the depressed fragment has been elevated.

The end-result study carried out by Dr. Maxfield has been well done. It is significant that the results in over 31 per cent. of his cases were judged as *excellent*, meaning that these individuals had no restriction of activity and no pain and were able to return to their regular occupation. Moreover, it is extremely important to note that four of the five men with results rated as *excellent* were covered by Workmen's Compensation Insurance. Certainly, the return of an individual to gainful employment would make the operation worthwhile.

(Continued on page 192)

EXPERIMENTAL STUDIES ON THE TREATMENT OF BONE AND JOINT TUBERCULOSIS WITH DIHYDROSTREPTOMYCIN AND ISONICOTINIC ACID HYDRAZIDE

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From the Clinic of Professor Bastos Ansart, Barcelona

Knowledge of the treatment of bone and joint tuberculosis by the new drugs specific for this infection is empirical. Most of the published studies concerning this form of therapy merely report the results observed in human illness, with some provisional conclusions concerning the possibilities of cure. Almost all of the basic problems concerning this treatment—as, for instance, the curative influence of the medicaments, sterilization of the lesions, and others—are not even discussed in such reports. It is obvious that our knowledge of these factors is incomplete. Tuberculosis of bones and joints is characterized by a great variety in the pathological changes, clinical manifestations, and the progression of the disease process. It is, therefore, difficult to standardize the results obtained with a new therapeutic agent. The lack of a sufficient number of cases which are strictly comparable makes any evaluation of different methods of treatment very difficult. Moreover, treatment of these patients is usually not limited to the administration of antibiotics but in most cases is carried out in association with classical orthopaedic and surgical procedures. Under these conditions it is rather difficult to determine the influence of each of these methods of treatment in the healing or improvement of the tuberculous process.

Although results obtained from animal experiments can be applied to clinical practice only with reservations, such experimental studies do afford objective information which can hardly be obtained by clinical observation alone.

Nevertheless, judging from the small number of articles in the literature, experimental investigations of bone and joint tuberculosis and its treatment are relatively few. Successful inoculation by ordinary methods has never been observed in autopsy reports in which visceral and glandular lesions have been carefully recorded. It is probable that in such animals the bacilli do reach the skeletal tissues, as well as other organs. This seems to be confirmed by studies in which the dissemination of bacilli in infected animals has been investigated [6], as well as by culture of marrow tissue in tuberculous guinea pigs and rabbits as was done by Attoire and Viallier. Usually, however, the bacterial implants remain unobserved and never furnish the necessary material for a therapeutic test.

For an experimental study of treatment of bone and joint tuberculosis it is necessary to produce the lesions by direct inoculation in the skeleton. We have done this in our experiments and have obtained a large number of lesions suitable for testing therapeutic methods. In this paper we intend to discuss briefly the method of inoculation and the results observed in these experimental lesions after treatment with dihydrostreptomycin and isonicotinic acid hydrazide.

MATERIAL AND METHODS

Rabbits and guinea pigs were used in all the experiments. Rabbits are more suitable because of their size, which facilitates both the inoculation and the pathological study of the lesions. Guinea pigs, on the other hand, are more sensitive to all kinds of bacilli, even the human strain, which is almost innocuous to rabbits. Moreover, they offer the important advantage of presenting a noticeable lymphatic reaction, which is never observed in rabbits and which offers valuable information about the course of the illness and the effects of treatment. In all the experiments only males were used, since it was felt that pregnancy in the females might alter the evolution of the disease. In each group, animals

FIG. 1-A

Extensive caseous focus in bone of a control rabbit, ninety days after inoculation.

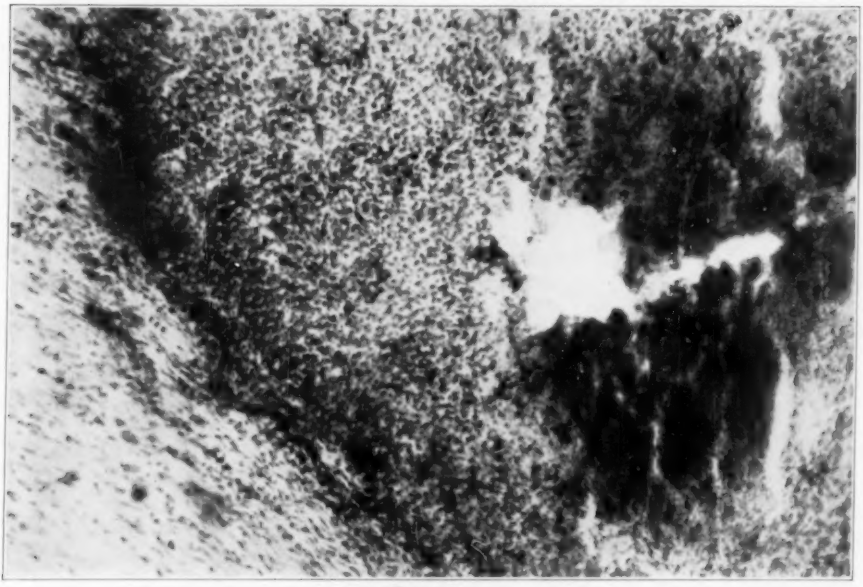

FIG. 1-B

Photomicrograph of the lesion shown in Fig. 1-A. Note the extensive infiltrative area around the caseous mass.

of the same strain, age, weight, and size have been used in order to obtain, in each case, identical or very similar lesions.

For the same reason, bacilli of identical strain were always employed: *Bacillus bovis Vallée*, obtained by subculture on potato and injected in the form of emulsions, with concentrations of 0.5 or 1 milligram of humid weight of culture per cubic centimeter of emulsion. These bacilli had been previously tested to prove their sensitivity to dihydrostreptomycin.

Infection of bone was obtained by inoculation on the lower end of the femur in rabbits; 0.05 cubic centimeter was injected into the marrow cavity through a small orifice made in the cortex with a special trocar. By this method, thirty days later the first lesions appeared in the infected bone like "wax spots" of a very small size. About the third month these spots conglomerated and in the control animals developed into large caseous foci which filled almost the entire marrow cavity, with softened areas in the center and a strong

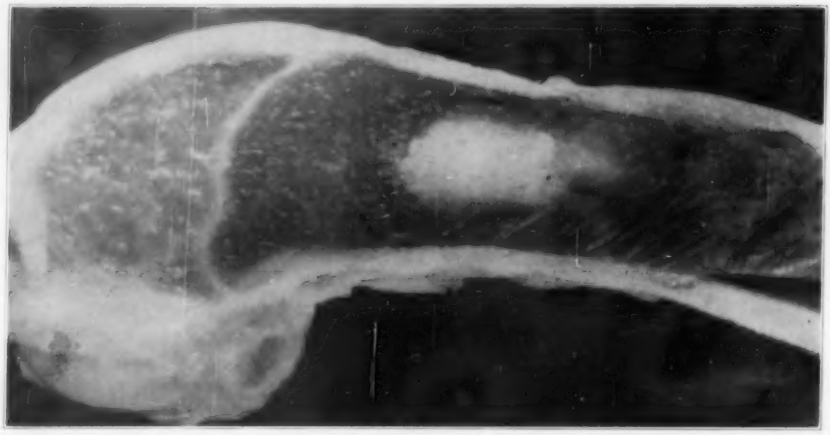

FIG. 2-A

Caseous focus in the femur of a rabbit treated with dihydrostreptomycin for fifty days.

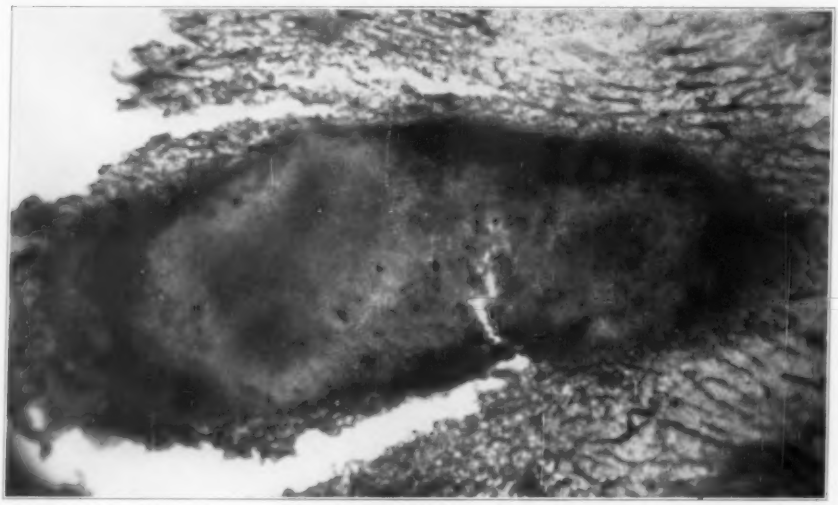

FIG. 2-B

Photomicrograph of the same lesion, showing the histological changes. Note the central caseous mass and the limitation of the perifocal area of infiltration.

lymphocytic reaction in the periphery (Figs. 1-A and 1-B). The main inconvenience of the procedure is that such lesions only appear in about one third of the inoculated animals, chiefly because of technical errors, which can easily be avoided. In experiments now being conducted, we are using a special technique for inoculation and thus hope to gain greater uniformity of experimental material. It should be pointed out that the marrow cavity of the femur in rabbits has almost no cancellous bone; experimental "osteitis", therefore, differs greatly from that in human subjects.

Infection of joints was produced in the knees of both rabbits and guinea pigs. In both animals this joint is well situated for this purpose. Under the patellar tendon there is a synovial fold into which it is easy to inject the emulsion through the tendon. In this way the organisms are injected into the synovial tissue and not into the joint cavity. The

amount of the injection varies from 0.05 to 0.1 cubic centimeter, with 0.5 milligram of bacilli per cubic centimeter of suspension.

By these means lesions which appear and develop with great uniformity can be obtained in almost all animals which have been inoculated. These lesions appeared about fifteen days after the inoculation as a specific inflammation in the injected synovial area. About one month later the process invaded the entire synovial membrane, producing a caseous synovitis (Fig. 4). In the later stages the entire articular surfaces were destroyed and the underlying bone was invaded. It was thus possible to produce a pathological condition closely simulating that found in clinical tuberculous arthritis. At the same time the infection spread outside the joint, appearing as extracapsular abscesses. The guinea pigs presented, in addition, a very noticeable lymphatic reaction which led to a caseous adenitis in the inguinal region (Fig. 6).

FIG. 3

Diagram showing the evolution of bone lesions in treated and untreated rabbits.

A: Small caseous lesion with perifocal infiltrative area forty-five days after inoculation, at the beginning of treatment with dihydrostreptomycin.

B: Large caseous focus and infiltrative area at the conclusion of the experiment, ninety-five days after inoculation, in a control animal.

C: Reduced caseous lesion with no perifocal infiltration at the conclusion of the experiment in an animal treated with dihydrostreptomycin.

Inoculation of joints, in our experience, has furnished a more uniform material than inoculation of bone. We have found the technical procedures to be very simple and the results are practically constant. Moreover, the pathological changes in experimental synovitis resemble the lesions found in human patients much more closely than do those in experimental "osteitis". For all these reasons, most of our therapeutic tests have been performed on experimental tuberculosis of the joints.

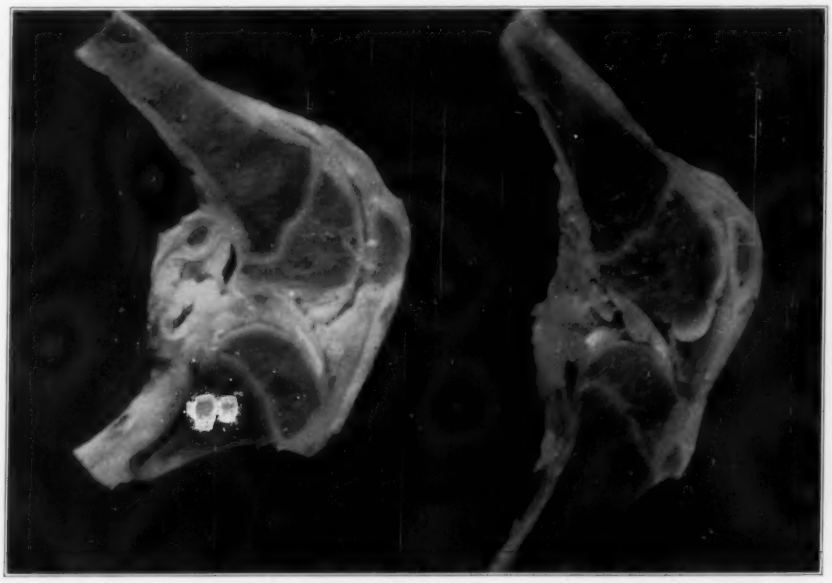

FIG. 4

Specimens from a control rabbit inoculated in the left knee, showing the swelling and thickening of the synovial lining. The normal knee is shown on the right.

ANATOMICAL CHANGES IN BONE LESIONS TREATED WITH DIHYDROSTREPTOMYCIN

Experimental procedure: Twenty rabbits were inoculated in the distal end of the femur by means of the technique described. Of these, ten were employed as controls and the remainder were treated with dihydrostreptomycin. The treatment was begun forty-five days after the inoculation and lasted one and a half months. The daily dosage was 0.1 gram administered in two injections every day.

Results: The results at the end of the experiment were as follows:

No. of controls		10
Without bone lesions	7	
With bone lesions	3	
No. treated with dihydrostreptomycin		10
Without bone lesions	6	
With bone lesions	4	

It is evident that there is little difference between the number of infected animals in both groups. However, the anatomical difference between the treated lesions and those not treated is very noticeable. In the latter a focus of caseation was found which filled nearly the entire marrow cavity (Fig. 1-A). Histological examination revealed a large area of lymphocytic infiltration, not clearly demarcated, around this mass. No defensive or productive reaction was observed (Fig. 1-B).

In animals treated with dihydrostreptomycin, the caseous focus was much smaller (about one millimeter). There were no areas of softening and the focus was clearly separated from the normal marrow tissue (Fig. 2-A). Histologically the peripheral zone of infiltration was very narrow and well demarcated (Fig. 4). No reaction of a defensive nature was observed in these treated animals.

FIG. 5-A

Specimens from a rabbit inoculated in the knee joint. Treatment with dihydrostreptomycin was begun on the day of inoculation. No changes are apparent in the gross specimen. The knee shown on the right was not inoculated.

A comparative study between treated and untreated animals with bone lesions permits some interesting deductions. It is probable that the absence of lesions in treated rabbits was not a consequence of treatment, for an almost identical situation occurred in the control animals. It may be concluded, therefore, that dihydrostreptomycin does not eliminate pre-existing bone lesions.

It is obvious, on the other hand, that the lesions in the treated animals were much smaller than those in the controls. The treatment, therefore, has a beneficial effect on the progression of the tuberculous lesions in bone. As has been stated, no defensive cellular reaction was observed, so that it would appear that the treatment had no influence on the regressive or curative process. At the same time the lesions observed in treated rabbits were very similar to those observed in animals which were sacrificed before treatment was begun (Fig. 3). It would seem,

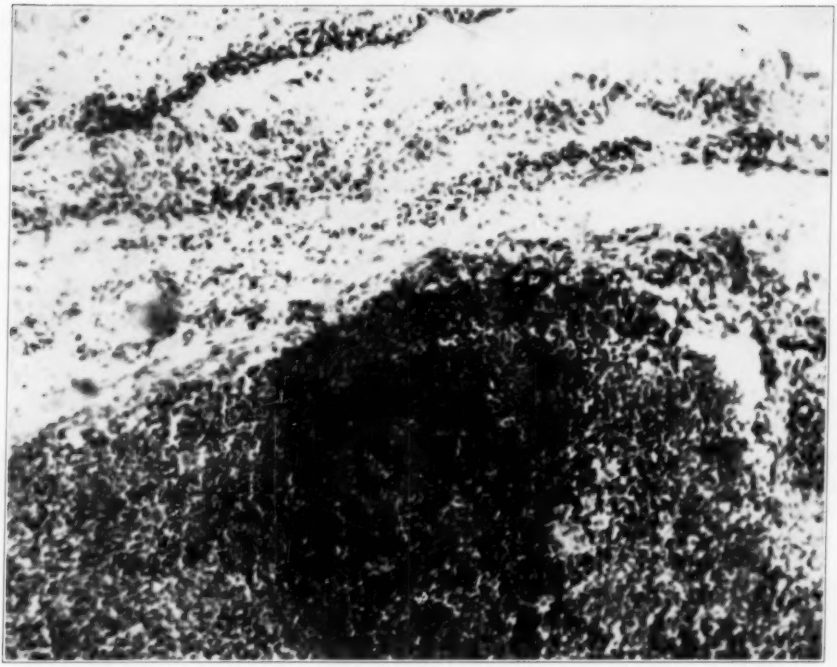

FIG. 5-B

Photomicrograph of the lesion shown in Fig. 5-A, showing the persistence of the histological changes in the synovial membrane.

FIG. 5-C

Photomicrograph showing the synovial membrane of the normal knee.

therefore, that the effect of dihydrostreptomycin is only to inhibit the progressive course of the illness.

This point of view seems to be confirmed by the histological examination. As has been said, the main difference between treated and untreated lesions is the extent of the peripheral infiltrative zone. In this zone occur the phenomena of further infiltration and progressive caseation which lead to the enlargement of the initial focus. The intensity of these phenomena depends, of course, on the aggressive activity of the bacillus or its toxins and on the reaction of the normal tissues which surround the lesion. The inhibitory influence of antibiotics can have the effect of decreasing this activity, so that there is no further peripheral infiltration and, therefore, a delay in enlargement of the area of caseation.

From these observations it seems reasonable to assume that, once the caseous focus has formed, the dihydrostreptomycin can act only to inhibit the progression of the specific alterations already present. It would seem to have very little influence or none on the process of healing of the existing lesion.

The results observed in these experiments are very similar to those obtained by Koch in an interesting paper on experimental bone tuberculosis and its treatment with streptomycin and several other therapeutic agents. Koch observed, as did the authors, a noticeable reduction in the size of experimental bone lesions of the femur in rabbits treated with streptomycin; however, he never observed complete elimination of the lesion.

ANATOMICAL CHANGES IN SYNOVIAL LESIONS TREATED WITH DIHYDROSTREPTOMYCIN AND ISONICOTINIC ACID HYDRAZIDE

1. *Knee Joints in Rabbits: Treatment Started on Day of Inoculation*

Experimental procedure: Fifteen rabbits inoculated in the knee joint were used in this experiment. Five of these were used as controls. Five were treated with dihydrostreptomycin for fifty days, with a daily dosage of 0.1 gram given in two injections. The other five rabbits were treated with isonicotinic acid hydrazide for the same period, with a daily dosage of six milligrams administered orally twice a day in concentrated solution. It is important to note that this treatment was begun on the day of inoculation, in order to observe the preventive effect of these drugs on the recent bacterial implants in the synovial membrane.

Results: The results in this group of experiments were as follows:

No. of controls		5
With extensive gross lesions	5	
No. treated with dihydrostreptomycin		5
With extensive gross lesions	0	
With limited gross lesions	2	
With microscopic lesions only	3	
No. treated with isonicotinic acid hydrazide		5
With extensive gross lesions	0	
With limited gross lesions	1	
With microscopic lesions only	4	

A considerable difference may be noted between the treated and the untreated animals. None of the treated animals presented, at the end of the experiment, the extensive lesions which were a constant finding in the controls. In the latter, the caseous synovitis extended throughout the joint (Fig. 4), while in the treated specimens it was limited to the area in which the inoculation had been made and, in most of these, the alterations were evident only upon microscopic examination (Figs. 5-A, 5-B, and 5-C).

It is important to note that all the animals treated under the conditions described showed, at the end of the experiment, persistence of the specific lesions. In fact, the complete disappearance of such alterations was not observed in any case. Even in those cases

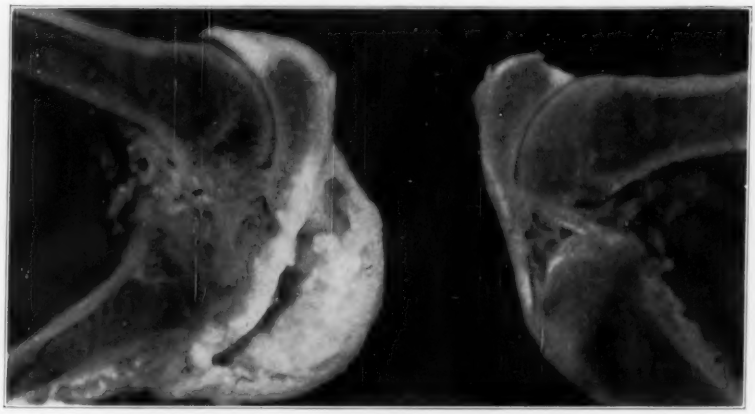

FIG. 6

Specimens from a control guinea pig sacrificed three months after inoculation, showing the intra-articular changes and an extracapsular abscess in the knee which had been inoculated. The normal knee is shown on the right.

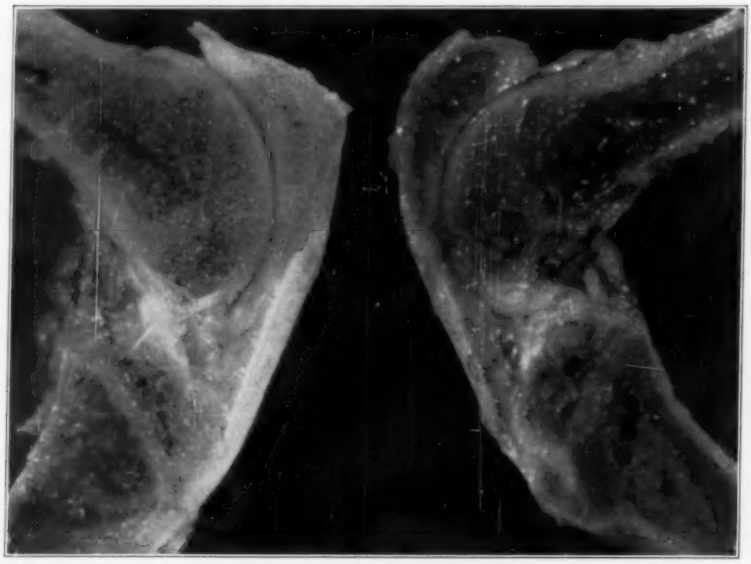

FIG. 7

Photograph showing the lesions in a guinea pig thirty-five days after inoculation, at the beginning of treatment.

in which gross examination showed no difference between the inoculated limb and the contralateral limb, histological studies revealed the presence of typical tuberculous lesions (Figs. 5-A, 5-B, and 5-C).

The authors wish to emphasize this fact, which they consider one of the most significant findings in their experiments. As has been said, most of the animals treated in this way presented only histological evidence of tuberculosis, but no macroscopic evidence. It is obvious that in a routine autopsy such lesions would not have been detected. Only through a careful study of the zone in which the lesions were expected to be, as was done in these experiments, is it possible to discover such microscopic evidence of tuberculous

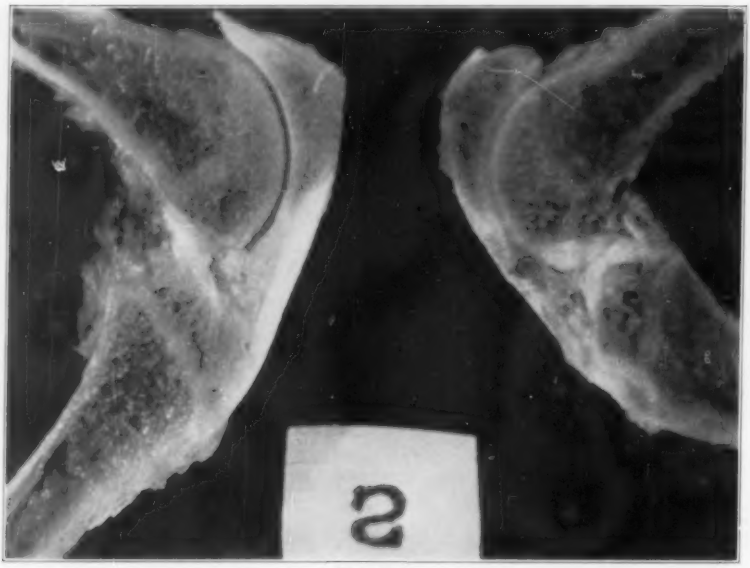

FIG. 8-A

Photograph showing anatomical changes in a guinea pig after treatment with dihydrostreptomycin.

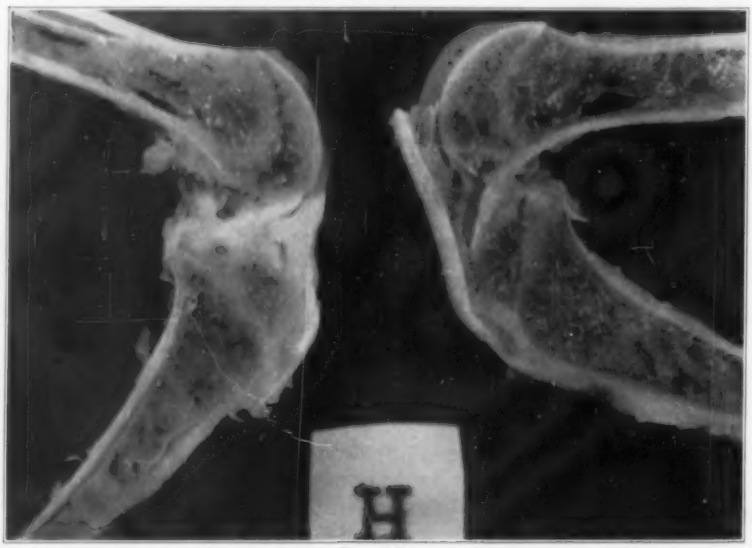

FIG. 8-B

Photograph showing anatomical changes in a guinea pig after treatment with isonicotinic acid hydrazide.

foci. The authors believe, therefore, that these studies afford more accurate information than can be obtained by other methods of experimentation *in vivo*.

Other studies on the inhibiting influence of streptomycin on recent synovial lesions have been reported in the literature. Pogolotti, in 1949, inoculated the knee joints of ten guinea pigs and four rabbits previously treated with streptomycin, in order to observe the

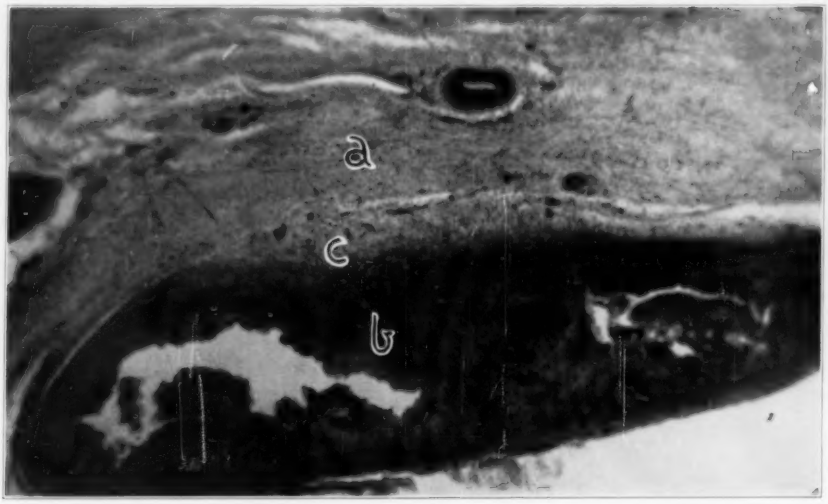

FIG. 9

Photomicrograph of the synovial membrane of a guinea pig treated with isonicotinic acid hydrazide, showing the persistence of histological changes, the demarcation of the infiltrative area, and the absence of a healing reaction; *a*, normal synovial tissue; *b*, caseous mass with some central areas of softening; *c*, pericaseous infiltrative area.

prophylactic effect of this drug on the development of tuberculous arthritis. At the end of his experiment he did not observe any favorable change in treated animals compared with controls. He concluded, therefore, that specific treatment will not prevent the development of hematogenous dissemination to the synovial tissues. This has also been our conclusion, since we observed the persistence of lesions in all treated animals. However, unlike Pogolotti, we have observed a great difference between treated and untreated rabbits, which offers clear-cut proof of the positive effect of the antibiotics.

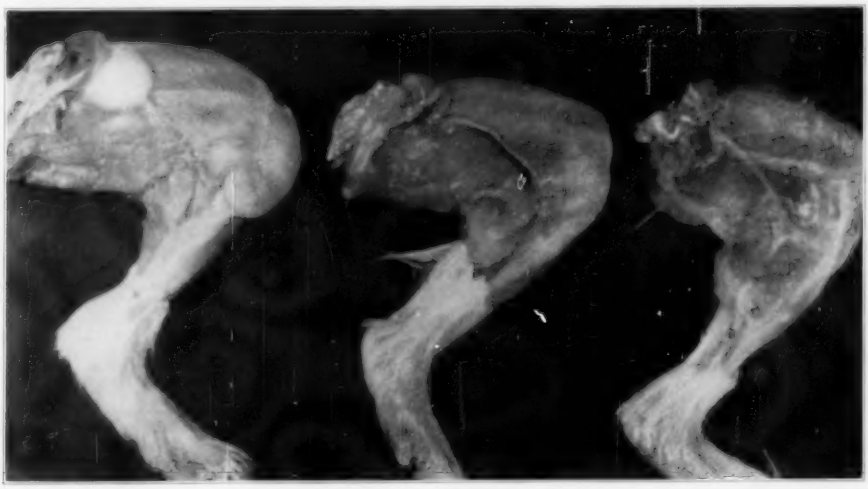

FIG. 10

Photographs of specimens from treated and untreated guinea pigs. On the left, a control animal; center, specimen from an animal treated with isonicotinic acid hydrazide; on the right, specimen from an animal treated with dihydrostreptomycin.

FIG. 11-A FIG. 11-B

Evolution of the lymphatic reaction in untreated guinea pigs.

Fig. 11-A: Photograph of a specimen removed thirty-five days after inoculation.

Fig. 11-B: Photograph of a specimen removed forty-five days later.

2. *Knee Joints of Rabbits: Treatment Started Forty-five Days after Inoculation*

Experimental procedure: Thirty rabbits were inoculated in the knee joint by the same technique as the previous group. Of these, ten were treated with dihydrostreptomycin and ten with isonicotinic acid hydrazide during a period of fifty days, and ten were used as

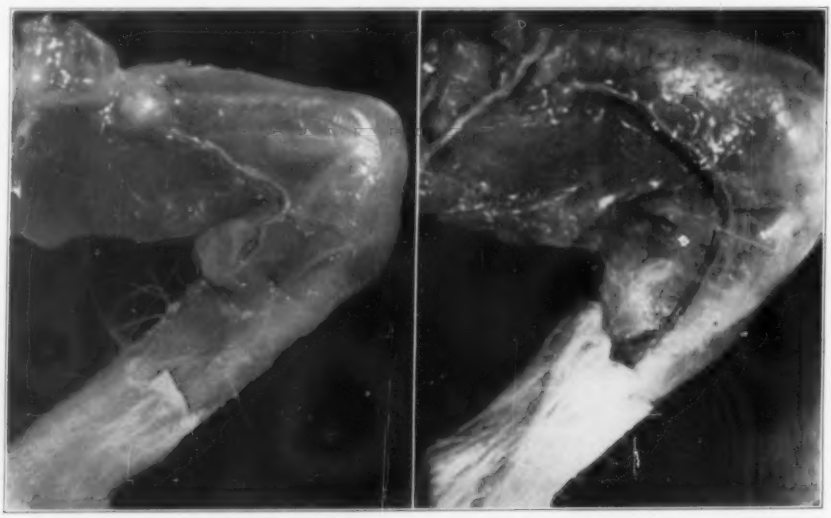

FIG. 12-A FIG. 12-B

Progression of the lymphatic reaction in guinea pigs treated with dihydrostreptomycin.

Fig. 12-A: Photograph of a knee joint removed thirty-five days after inoculation, at the beginning of treatment.

Fig. 12-B: Photograph of a knee joint removed after forty-five days of treatment with dihydrostreptomycin.

controls. The dosage was the same as in the previous experiment, but treatment was not initiated until forty-five days after the injection, when all the animals showed swelling and clinical evidence of tuberculous infection of the joint.

Results: All of the treated animals, both those treated with dihydrostreptomycin and those treated with isonicotinic acid hydrazide, showed caseous infiltration of the entire joint at the end of the experiment. Grossly and histologically this differed very little from the lesions observed in the ten animals used as controls.

It is obvious that in these cases treatment had no influence, or at least very little influence, on the progress of the synovial infection. However, the conditions in this experiment differed greatly from those in the preceding experiments. In this group treatment was not administered until the lesions showed an advanced stage of development. They did not show significant changes during the period of treatment compared to the control animals. It appears, therefore, that by the time treatment was begun the lesions were in a stage of inactivity or stabilization.

3. *Knee Joints of Guinea Pigs: Treatment Started Thirty-five Days after Inoculation*

Experimental procedure: Forty guinea pigs were used in this experiment and were divided into four groups:

Group I: Ten control animals sacrificed at the end of the experiment (at three months);

Group II: Ten control animals sacrificed thirty-five days after inoculation, at the time when treatment was begun in Groups III and IV, in order to study the pathological changes present when treatment was begun;

Group III: Ten animals treated with dihydrostreptomycin during fifty days with a dosage of 0.04 grams per day. Treatment was begun thirty-five days after inoculation;

Group IV: Ten animals treated with isonicotinic acid hydrazide for the same number of days and at the same time as the animals in Group III, with a dosage of six micrograms a day.

Results: All the animals in Group I (controls sacrificed at the end of the experiment) showed extensive involvement of the infected joint, with extracapsular abscesses and marked lymphadenitis in the inguinal region (Fig. 6).

The animals in Group II (controls sacrificed thirty-five days after infection, without treatment), showed much smaller lesions. There was caseation and infiltration of the synovial membrane, with very slight swelling of the joint. No extra-articular spread was noted and the lymphatic reaction was confined to a moderate adenitis of a single gland (Fig. 7).

In Groups III and IV (treated with dihydrostreptomycin and isonicotinic acid hydrazide, respectively, beginning thirty-five days after inoculation) the pathological changes were even less evident. The infiltration of the synovial membrane was barely apparent and in most cases was evident only upon histological examination. There was little swelling of the joint and no extra-articular spread (Figs. 8-A and 8-B). No gross evidence of lymphadenitis was found in most of the cases, and only accurate dissection and histological examination demonstrated the presence of this reaction. Nevertheless, in all of the specimens it was possible to demonstrate, by these means, the persistence of specific tuberculous lesions, both in the synovial membrane and in the corresponding lymph glands (Figs. 9 and 10). On the whole, all of these lesions were somewhat smaller than those in Group II but very similar to them.

It is important to note the development of the lymphatic lesions under treatment. As was demonstrated in Group II, all the inoculated animals showed, at the beginning of treatment, a small but distinctly noticeable adenitis in the inguinal region, with evident involvement of the lymphatics. The evolution of this lymphatic reaction was quite different in the treated and the untreated animals. In the former, the adenitis apparently disap-

peared about fifteen days after the beginning of treatment and there was no visible evidence of lymphangiitis. In untreated animals, on the other hand, the adenitis was very noticeable as a caseous adenitis involving several glands and there was a marked lymphangiitis (Figs. 12-A and 12-B). The similarity of the lymphatic reaction here to that occurring in the primary complex of a pulmonary tuberculous infection is noteworthy.

The difference observed between the treated animals and the controls sacrificed at the time treatment was begun in the other groups shows the great influence of treatment on experimental joint tuberculosis. However, as in former experiments, it was not possible to prove the total disappearance of all evidence of infection. Moreover, it was not possible to demonstrate even a positive curative or regressive influence on these initial lesions. If the similarity between the specimens of Group II and those of Groups III and IV is considered, it will be realized that there is not a great difference in the lesions before and after treatment, except for the changes in the lymphatic complex. This appears to confirm the fact that the main influence of the drugs consists in delaying the progression of the infection rather than in actually curing it. On this basis it should also be possible to explain the apparent contradiction between these results and those in the preceding experiment. In this series treatment was administered during the active or progressive stage of the infection, as was shown by the difference between the specimens of Groups I and II, while in the preceding series the treatment coincided with a period of inactivity or stabilization of the tuberculous infection.

SUMMARY AND CONCLUSIONS

The results observed in different specimens allow us to draw some preliminary conclusions concerning the influence of treatment with dihydrostreptomycin and isonicotinic acid hydrazide on the anatomical changes of tuberculous lesions. These conclusions may be summarized as follows:

Dihydrostreptomycin and isonicotinic acid hydrazide administered in large quantities do not appear to bring about a complete reversal of specific changes. This was found to be true even when treatment was begun simultaneously with the inoculation.

In almost all of the cases treatment proved highly beneficial in respect to progression of the experimental lesions. In all treated animals the lesions were smaller than in the controls and were more sharply demarcated. The drugs appeared to have the greatest influence on the development of the lymphatic lesions. In no instance was there histological evidence of cure or of the development of a productive or cicatricial reaction as the result of treatment.

A comparative study of specimens obtained before and after treatment showed that the main action of the drug is to inhibit the spontaneous progressive course of the process. There is little influence on its regression.

A comparison between animals treated with dihydrostreptomycin and isonicotinic acid hydrazide in equivalent doses shows almost no difference between the effects obtained with the two drugs.

REFERENCES

1. Bastos Mora, Felipe: Contribución al estudio de la tuberculosis experimental del esqueleto y su tratamiento con la estreptomicina y la hidrácida. Cir. del Aparato Locomotor, **9:** 504–509, 1952.
2. Bastos Mora, Felipe, y Portal Llamedo, Luís: Estudios experimentales sobre el tratamiento de la tuberculosis osteoarticular. Arch. de Pediat., **3:** 519–531, 1953.
3. Koch, H.: Die Wirkung spezifischer Medikamente bei der Knochen- und Gelenktuberkulose im Tierversuch. Verhandl. d. Deutschen Orthop. Gesellsch., 1950. Zeitschr. f. Orthop., **80:** 192–201, 1951.
4. Pogolotti, Renato: La streptomicina può prevenire l'artrite tubercolare? Minerva Med., **40** (1): 812–815, 1949.
5. Portal, Lusics: Resultados observados con el empleo de la estreptomicina y la hidrácida en la tuberculosis articular del conejo. Cir. del Aparato Locomotor, **9:** 510–516, 1952.
6. Soltys, M. A., and Jennings, A. R.: Dissemination of Tubercle Bacilli in Experimental Tuberculosis in the Guinea Pig. Am. Rev. Tubere., **61:** 399–406, 1950.

RIGID VALGUS FOOT DUE TO TALOCALCANEAL BRIDGE *†

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In 1948, Harris and Beath [3] reported that fifteen of their seventeen cases of rigid valgus foot (peroneal spastic flat-foot) were due, not to peroneal spasm, but to congenital fusions of the major tarsal bones. They were able to recognize two such congenital anomalies. The first, calcaneonavicular bar, had already been recorded as a cause of rigid valgus foot by Slomann in 1921 and by Badgley in 1927. The second congenital anomaly, talocalcaneal bridge, for the first time was reported by them as a cause of rigid flat-foot, although it had been recognized by anatomists for fifty years as a deviation from normal structure.[8]

The present paper records further experience with the variety of rigid valgus foot which is due to talocalcaneal bridge and calls particular attention to a group of cases in which the anomaly falls short of producing a complete bony bridge from talus to calcaneus and hence is more difficult to recognize both clinically and roentgenographically.

REVIEW OF KNOWLEDGE RESPECTING TALOCALCANEAL BRIDGE

The fundamentals of the problem may be reiterated briefly. The foot problem with which we are here concerned is due to a congenital bond between the talus and the calcaneus on their medial surfaces. This anomaly is one of a group, all of which result in stiff and deformed feet. The clinical picture is commonly designated "rigid flat-foot" or "peroneal spastic flat-foot". In the fully developed type of the lesion we are now discussing, in which a solid bridge of bone unites the talus to the calcaneus, neither of these terms accurately describes the condition, since the foot is not always flat and the peroneal muscles are not always in spasm. Even when peroneal spasm is present, it is not a primary etiological factor but is secondary to strains which result when abnormal stresses are imposed upon a tarsus in which movement is limited. The term "rigid valgus foot" is a broader and more widely applicable designation, especially when followed by the name of the anomaly which is its cause.

There are two elements in the clinical picture: (1) deformity and (2) absence or great limitation of movement at the subtalar joint.

The *degree of deformity* varies within wide limits; it may be slight or it may be severe. In a characteristic case of moderate severity, there is a valgus tilt of the heel and usually valgus at the mid-tarsal joint also (Figs. 1-A, 1-B, and 1-C). The more severe cases, in addition, have marked depression of the longitudinal arch. In many cases the deformity is slight, even though there is complete fusion of the talus to the calcaneus. The severity of the deformity does not necessarily correspond with the degree of structural anomaly. The deformity is continuously present. It cannot be corrected voluntarily and does not disappear when the feet are relieved of superimposed weight, because the fixation of the subtalar joint precludes movement.

Loss of movement at the subtalar joint is always present and is the most characteristic feature of the lesion. The examiner may have difficulty in satisfying himself on this point. Tilt of the talus within the mortise of the ankle joint and movement at the mid-tarsal joint may give a false impression that the calcaneus does invert under the talus. The method of examination should be concentrated upon movement of the calcaneus under the talus. This can best be accomplished by grasping the heel without regard to the fore part of the foot and attempting to tilt it into inversion and eversion. The foot should be main-

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FIG. 1-A FIG. 1-B FIG. 1-C

Fig. 1-A: A characteristic example of severe rigid valgus foot on the left side, showing flattening of the longitudinal arch and valgus of the mid-tarsal joint. (Reproduced, by permission of E. and S. Livingstone Ltd., from *The Journal of Bone and Joint Surgery*, **30-B**: 630, Nov. 1948.)

Fig. 1-B: The deformity persists unchanged when weight is removed from the feet.

Fig. 1-C: Valgus of the heel is evident in the photograph.

tained at right angles to the leg in order to eliminate tilting of the talus in the ankle joint. This manoeuvre makes it possible to ascertain that there is little or no movement at the subtalar joint.

The attempt to invert the calcaneus beneath the talus causes the peroneal tendons to become taut, especially if the foot is in plantar flexion at the ankle joint, so that some tilting of the talus can occur. This gives an impression that the peroneal muscles are in spasm. In most cases there is no spasm of the peroneal muscles; the apparent spasm is merely tautness of the peroneal tendons, which have shortened in adaptation to a long-continued valgus deformity. Under certain circumstances, however, peroneal spasm may be present. It occurs when abnormal stresses have strained those tarsal joints in which there still is movement (the talonavicular joint, or the talocalcaneal joint when fixation of that joint is incomplete, the result of an incomplete talocalcaneal bridge). Formerly we believed that peroneal spasm did not occur in rigid valgus foot and that what appeared to be peroneal spasm was in reality tautness of the peroneal muscles. In the majority of cases this is true, but study of the cases of incomplete talocalcaneal bridge reported in this paper demonstrates that peroneal spasm can occur when such a foot is wrenched. It should be emphasized, however, that peroneal spasm is not the cause of rigid valgus foot but is the consequence of stress upon a foot the movements of which are abnormally limited.

Rigid valgus foot due to talocalcaneal bridge (as well as to other anomalies of bone structure) probably exists from birth. An observant parent sometimes detects the rigidity of the foot in early childhood, even in the absence of deformity. Occasionally, a patient is seen with severe deformity which has been present from birth (congenital calcaneovalgus).

In early life rigid valgus foot causes few or no symptoms. Incomplete talocalcaneal bridge is more apt to cause symptoms, which appear at an earlier age and are more severe than complete talocalcaneal bridge. In childhood, disability from pain usually is not great even when deformity is severe. A significant degree of foot discomfort is apt to appear first in adolescence or in young adult life; sometimes it does not appear until middle life. Trauma is often the final factor which gives rise to symptoms; this may take the form either of a single injury, such as a fall or jump, or of repeated daily stresses as in marching or long hours of duty on the heaving deck of a ship at sea.

Our present experience leads us to the belief that most, if not all, of the cases of rigid valgus foot unrelated to arthritic disease are due to congenital fusions of the tarsal bones.

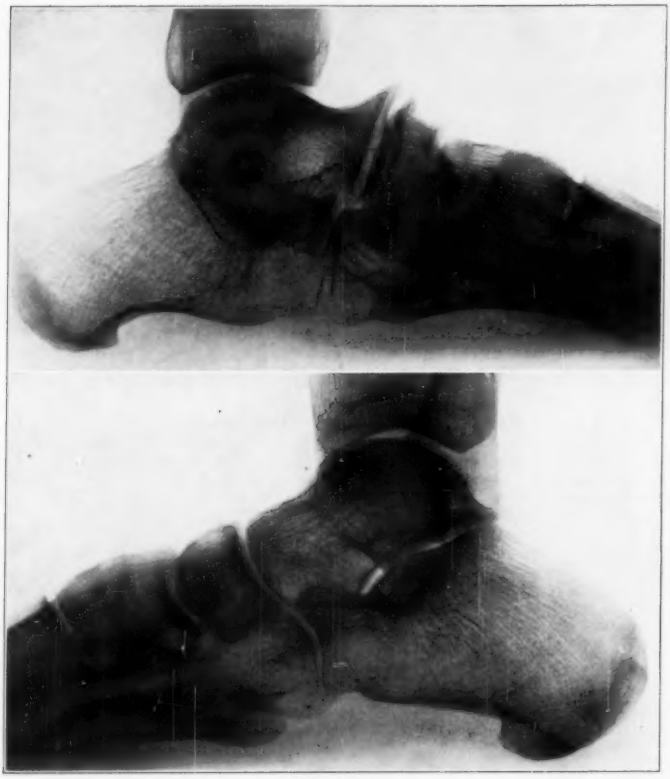

FIG. 1-D

Upper view: Lateral roentgenogram of the rigid left foot, which shows marked lipping of the talonavicular joint, marked thinning of the articular space of the talocalcaneal joint, and obliteration of the joint between the sustentaculum tali and the neck of the talus.

Lower view: Roentgenogram of the normal right foot. (Reproduced, by permission of E. and S. Livingstone Ltd., from *The Journal of Bone and Joint Surgery*, **30-B:** 631, Nov. 1948.)

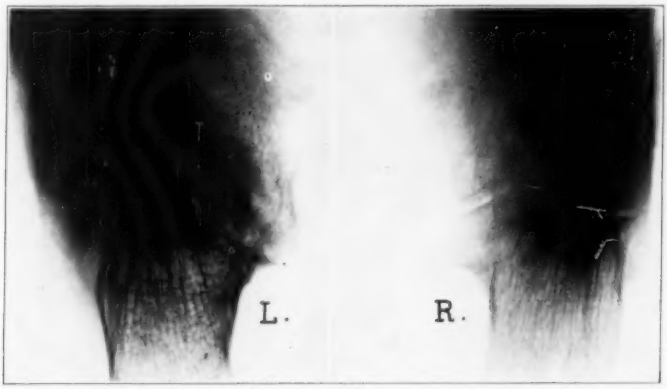

FIG. 1-E

Oblique posterosuperior projections showing the normal joint between the sustentaculum tali and the neck of the talus in the right foot and the bony bridge between the talus and the calcaneus in the left foot. (The roentgenograms shown in Fig. 1-E were obtained by the technique shown in Fig. 3.) (Reproduced, by permission of E. and S. Livingstone Ltd., from *The Journal of Bone and Joint Surgery*, **30-B:** 631, Nov. 1948.)

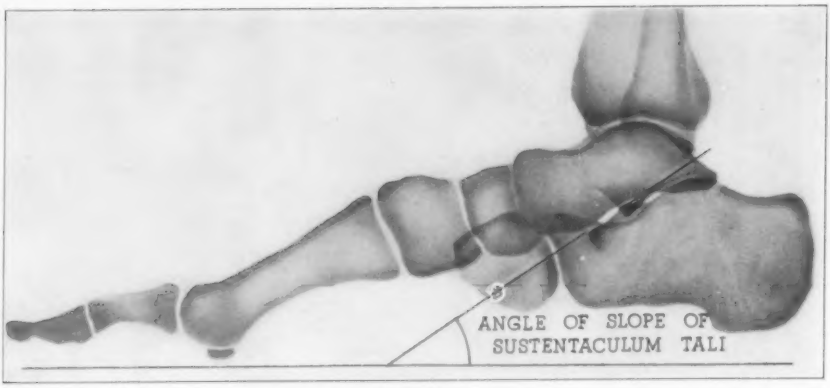

FIG. 2

Drawing showing the angle of slope of the sustentaculum tali. With the patient standing and the foot roentgenographed with a horizontal beam, the slope of the articular facet of the sustentaculum tali can be visualized. When the slope is projected down to the horizontal base line, it forms an angle which can be measured. This angle of slope of the sustentaculum tali varies within wide limits (from 10 to 60 degrees), but in the vast majority of cases (90 per cent.) it falls within a range of 25 to 45 degrees, and in 60 per cent. within a range of 28.5 to 40 degrees.[8]

FIG. 3

Photograph showing the roentgenographic projection necessary to reveal the presence of a talocalcaneal bridge. The angle of projection is from behind, forward and downward. Two or three roentgenograms should be made with projection angles of 45, 40, and 35 degrees. (Reproduced, by permission of E. and S. Livingstone Ltd., from *The Journal of Bone and Joint Surgery*, **30-B**: 625, Nov. 1948.)

These fusions frequently develop from accessory tarsal bones which fail to become separate entities but are attached to the tarsal bones adjacent to them (os sustentaculare in the case of talocalcaneal bridge).

Peroneal spasm is certainly a factor in producing a valgus deformity in feet which are attacked by rheumatoid arthritis. Eventually these feet become rigid in the valgus position because of damage to the tarsal joints. However, these cases of rigid valgus foot form a group by themselves easily recognized as part of a generalized arthritic disease causing deformities in feet which had previously been normal.

Roentgenography is an important agent in the diagnosis of these congenital tarsal fusions, as indeed it is in all structural foot problems. Harris and Beath[3], in 1948, recommended a roentgenographic technique which displayed the talocalcaneal bridge when it was complete or nearly complete. In a normal foot an x-ray beam, projected through the foot from behind, downward and forward, at an angle of 45 degrees or somewhat less, will pass through the plane of the joint between the sustentaculum and the neck of the talus, clearly revealing this joint. When a talocalcaneal bridge is present, the shadow of its mass obscures the joint. In its place a bony knob is seen. The resulting roentgenogram is distinctive especially when the lesion is unilateral, so that the abnormal foot can be compared with the normal foot (Figs.

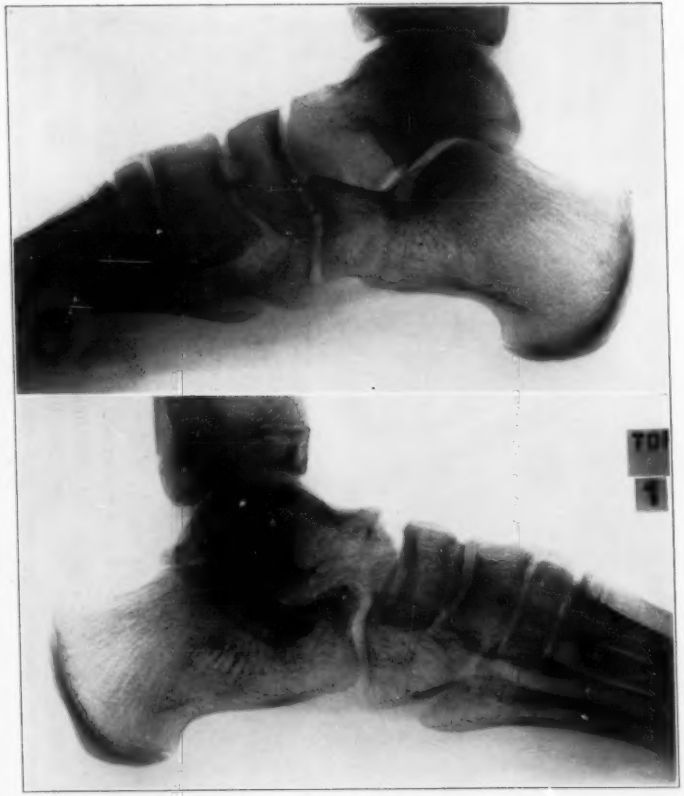

FIG. 4-A

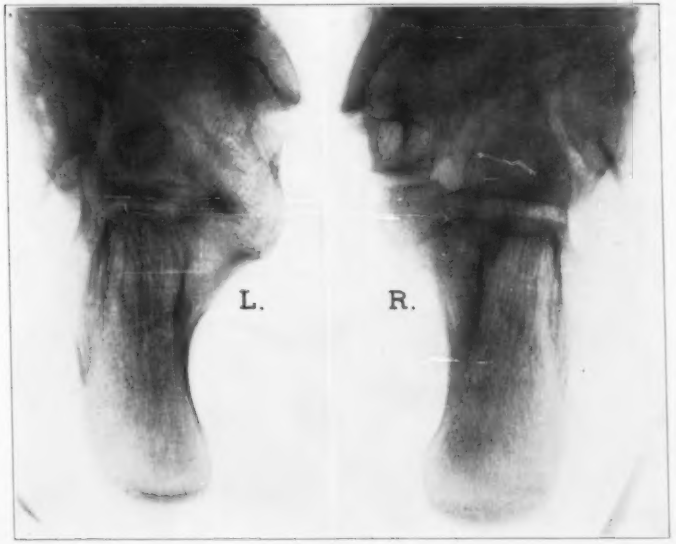

FIG. 4-B

Fig. 4-A: *Upper view:* A normal right foot in a thirteen-year-old child.

Lower view: The rigid valgus foot on the left side, with moderate lipping of the anterosuperior corner of the head of the talus, thinning of the articular space in the talocalcaneal joint, and disappearance of the joint between the sustentaculum tali and the neck of the talus. (Reproduced, by permission of E. and S. Livingstone Ltd., from *The Journal of Bone and Joint Surgery,* **30-B:** 628, Nov. 1948.)

Fig. 4-B: In the left foot a bridge of bone fusing the talus and the calcaneus is visible, in contrast to the normal right joint. (See also Fig. 10.) (The roentgenograms in Fig. 4-B were made by the technique illustrated in Fig. 3.) (Reproduced, by permission of E. and S. Livingstone Ltd., from *The Journal of Bone and Joint Surgery,* **30-B:** 628, Nov. 1948.)

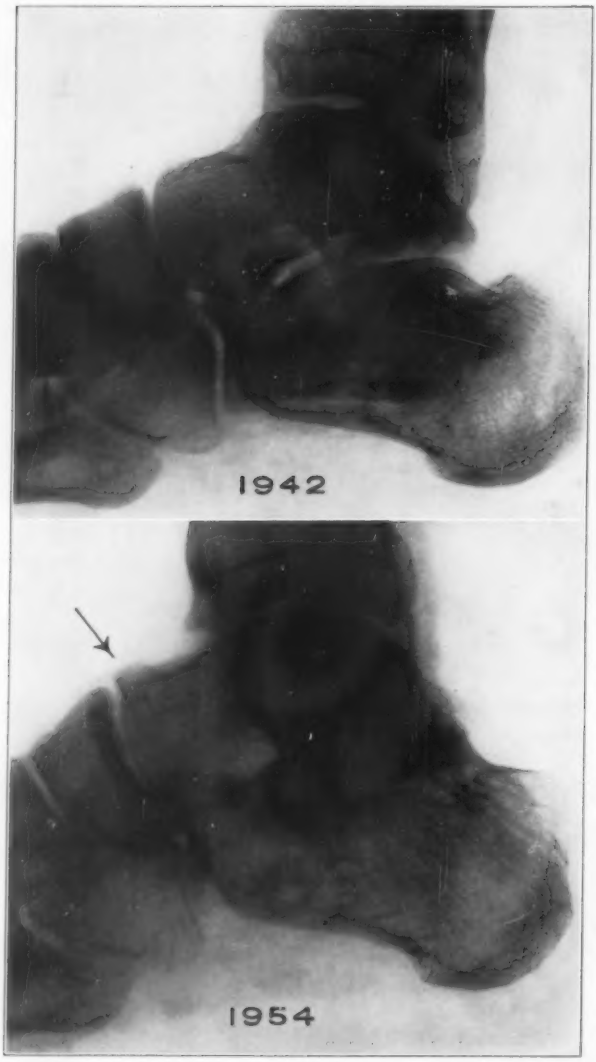

FIG. 5

Fig. 5: Subtalar fusion in the treatment of fracture of the calcaneus, resulting in lipping of the head of the talus.

Upper view: Roentgenogram made in 1942, at the time of accident.

Lower view: Roentgenogram made in 1954, eight years after subtalar fusion. Obliteration of movement in the subtalar joint distorted movement in the talonavicular joint. This was manifested by the development of a small beak at the anterosuperior corner of the head of the talus (arrow). When this results from a congenital anomaly such as a talocalcaneal bridge, the effect is greater, since the stresses of abnormal movement in the joint are accentuated by growth.

1-E, 2, 3, and 4-B). If the anomaly is incomplete, however, it may be difficult to demonstrate its presence by roentgenogram.

In addition to the primary lesion, roentgenography can demonstrate secondary changes of great significance. Fixation of two major tarsal bones (in this instance the talus and the calcaneus) disturbs the complex perfection of movement in the subtalar-mid-tarsal set of joints and results in abnormal binding and cramping of joint surfaces at the extreme of the arc in some planes of movement. This results in osteo-arthritic lipping, most conspicuous at the superior margin of the head of the talus.

Furthermore, the talocalcaneal bridge which binds these two bones together interferes with the development of the articular cartilage of the subtalar joint; this is recognizable in the lateral roentgenogram by thinning of the subtalar joint space (Figs. 1-D and 4-A).

In the lateral roentgenogram there also can be noted the absence of a clear picture of the joint between the sustentaculum tali and the neck of the talus (Figs. 1-D and 4-A).

That lipping of the superior margin of the head of the talus results from obliteration of movement at the subtalar joint is evidenced by the development of this change after arthrodesis of the subtalar joint in the treatment of fractures of the calcaneus. Figure 5 shows a case in which such osteo-arthritic lipping developed over a period of eight years. It must be recorded, however, that cases of talonavicular lipping following operative fusion of the subtalar joint in adults are infrequent. Perhaps the nearly constant

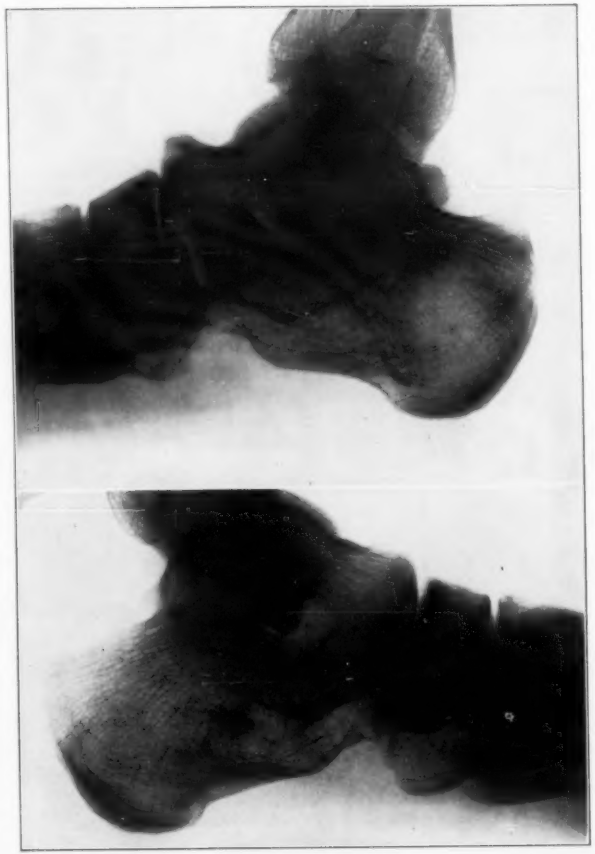

FIG. 6-A

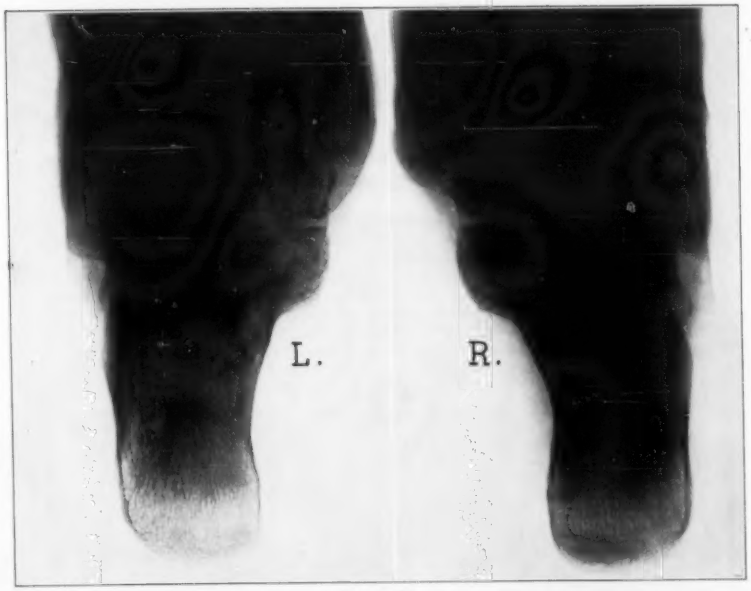

FIG. 6-B

Fig. 6-A: *Upper view:* Roentgenogram of a painful rigid valgus foot on the right due to incomplete talocalcaneal bridge in a workman, twenty-five years old. He had had no symptoms until he sustained an injury to his right foot at work. From then on he was seriously handicapped by persistent pain in the right foot. Note the characteristic lipping of the head of the right talus and obliteration of the joint spaces between the talus and the calcaneus, as well as between the sustentaculum tali and the neck of the talus.

Lower view: The left foot was also stiff, but it was painless. There was no beak on the head of the talus, but there was obliteration of the subtalar and sustentacular joint spaces. The right foot had the incomplete type of talocalcaneal bridge illustrated in Fig. 11.

Fig. 6-B: Oblique posterosuperior roentgenograms clearly revealed the joint between the sustentaculum tali and the neck of the talus in both feet, despite the clinical evidence of stiffness at both subtalar joints and the secondary changes in the right talonavicular joint.

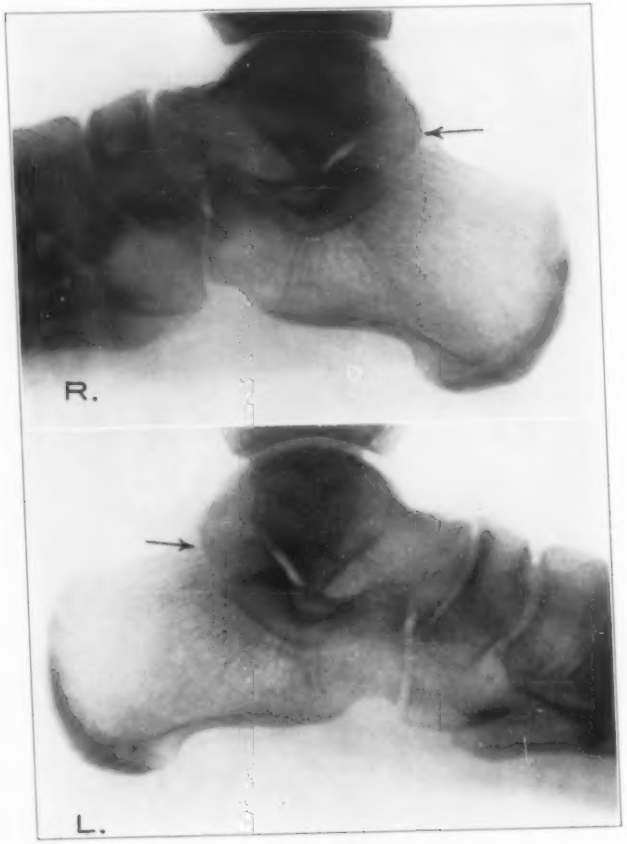

FIG. 7-A

FIG. 7-B

Fig. 7-A: Lateral roentgenograms of the feet of a seventeen-year-old boy who had suffered from painful, stiff feet for seven years. There was moderate deformity. Operation revealed an incomplete talocalcaneal bridge due to a talar bone mass overlapping the medial side of the calcaneus (see Fig. 12). The significant features of these roentgenograms are thinning of the subtalar joint space and lack of visualization of the joint between the sustentaculum tali and the neck of the talus. The overhanging mass from the talus in both feet can be seen at the points indicated by arrows. There was no lipping at the talonavicular joint.

Fig. 7-B: Oblique posterosuperior views of both feet. The joint between the sustentaculum tali and the neck of the talus can be seen clearly on both sides.

presence of these changes with congenital fusions, such as talocalcaneal bridge, is caused by stresses resulting from growth superimposed upon stresses due to abnormal movement. Long-term assessment of the small children upon whom Grice has performed his valuable operation should throw some light on this problem.

EXPERIENCE WITH CASES OF INCOMPLETE TALOCALCANEAL BRIDGE

It was formerly our opinion that probably all cases of talocalcaneal bridge could be visualized by this roentgenographic technique. Even those cases in which the bridge of bone was not quite complete, the narrow gap being filled by a bond of fibrous tissue or cartilage, still displayed the shadow of an abnormal mass of bone (Fig. 4-B). At that time we had not encountered a case of rigid valgus foot which could not be demonstrated by roentgenogram to be due either to calcaneonavicular bar or to talocalcaneal bridge. In the ensuing years, however, we have encountered several characteristic cases of rigid valgus foot which displayed no direct roentgenographic evidence of these congenital fusions. Conversation and correspondence with our colleagues indicate that they also have had difficulty in demonstrating that every case of rigid valgus foot is associated with a bony anomaly which can be demonstrated by roentgenogram. We have therefore devoted much thought, time, and effort to the investigation of these cases and report our findings in this paper.

Most of these patients with rigid valgus feet without roentgenographic evidence of a congenital fusion of the tarsal bones presented the characteristic secondary osteo-arthritic lipping of the superior margin of the head of the talus (Fig. 6-A). This is evidence that movement at the subtalar joint is limited and distorted. It seemed reasonable, therefore, to look for some mechanical interference with the movement of this joint, even though roentgenographic evidence was lacking. Of the two anomalies which are known to cause this secondary joint change, calcaneonavicular bar is relatively easy to demonstrate by an oblique roentgenogram. The demonstration of talocalcaneal bridge requires much more careful roentgenographic technique. It seemed possible that these exceptional patients might be suffering from an incomplete talocalcaneal bridge so disposed that it could not readily manifest itself in the roentgenogram.

On this reasoning we have operated upon ten cases and have had the opportunity to observe four other cases operated upon by our colleagues. The operative approach was from the medial side and in every case it was possible to demonstrate that the movement of inversion at the subtalar joint was grossly impaired by an abnormal bone mass which acted as a block. In nine cases the bone block was attached to the posterior margin of the sustentaculum tali. It was not sufficiently large to reach and fuse to the body of the talus and the tip of the mass was separated from the talus by connective tissue. However, it was of such a size and so disposed that, when the calcaneus began to invert beneath the talus, the tip of the mass impinged on the medial side of the body of the talus and obstructed further movement. It thus acted as a bone block to hold the heel in valgus (Fig. 11). The remaining five cases were most interesting, for in these bilaterally rigid valgus feet a small mass of bone attached to the body of the talus projected downward across the subtalar joint to overlap the medial side of the body of the calcaneus, immediately posterior to the sustentaculum tali. It resembled a malleolus and formed a mortise enclosing the upper and medial surfaces of the calcaneus. There actually was a true articular surface on the deep side of the mass covered with articular cartilage and a corresponding articulation on the medial surface of the body of the calcaneus (Fig. 12).

So far every case of rigid valgus foot lacking direct roentgenographic evidence of talocalcaneal bridge which we have explored has presented the phenomenon of bone blocking, due either to a bone mass springing from the posterior margin of the sustentaculum and impinging upon the body of the talus, or to a lip projecting downward from the body of the talus to overlap the articular margin of the calcaneus. These bone masses are

so disposed that they do not obstruct the x-ray beam when projected downward and forward through the plane of the joint between the sustentaculum tali and the neck of the talus. Hence their presence is not directly revealed by roentgenograms. So far we have not been able to devise a roentgenographic technique which will reveal them.

Many cases of talocalcaneal bridge consist of two bony masses, one springing from the talus, intimately bound by fibrous tissue or cartilage to a similar mass springing from the sustentaculum tali (Fig. 10). It seems probable that this tarsal anomaly is derived from two elements contributed respectively by the talus and the calcaneus. In the more advanced cases, the talar and the calcaneal elements fuse into a solid bridge of bone (Fig. 9) or meet one another and are bound together by dense fibrous tissue (syndesmosis) or by cartilage (synchondrosis) (Fig. 10). It now seems evident that there can be cases in which only a single element exists, which may be either calcaneal or talar. It may not be revealed by roentgenograms, but its size and position are such that it acts as a bone block to obstruct inversion and hold the heel in valgus.

On the basis of our present knowledge it may be concluded that, in addition to the fully developed examples of talocalcaneal bridge described in 1948[3], there are examples of incomplete development of this anomaly. They are not capable of direct demonstration by roentgenogram, although the roentgenogram may demonstrate secondary changes due to anchoring of movement in the subtalar joint. These incomplete lesions can be demonstrated only by operative exposure. They cause rigid valgus foot by acting as a bone block.

Since this type of lesion cannot be visualized directly by roentgenogram, the diagnosis must be made from the history, the clinical findings, and the presence of secondary roentgenographic changes.

The history often presents some features which are characteristic. Some patients present themselves for treatment early, in adolescence or in early adult life. This group have had some mild trouble with the involved foot since childhood, which has become steadily worse with approaching maturity, until finally the discomfort is sufficiently distressing to demand relief. Another group, about equal in numbers, have had no foot troubles of any kind until, in young adult life, they have suffered a wrenching injury. This gives rise to persistent pain of moderate or greater severity, which often is accompanied by peroneal spasm. We take this to be evidence that the foot with incomplete talocalcaneal bridge in which movement at the subtalar joint is limited by a bone block is vulnerable to strain when subjected to great wrenching force. When such a tarsal sprain occurs, the resulting pain persists for a long time. Some patients recover with prolonged rest, but in others pain and disability persist until the subtalar and talonavicular joints are fused.

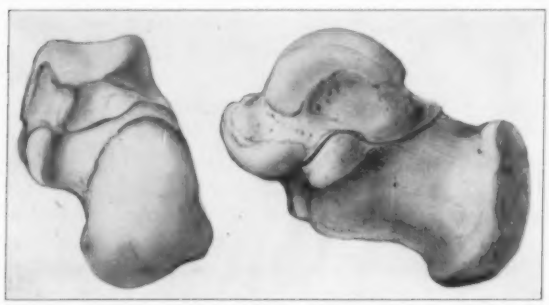

FIG. 8

FIG. 9

Fig. 8: Drawing illustrating the normal relationship of the talus to the calcaneus in the right foot viewed from behind and from the medial side. Compare with Figs. 9, 10, 11, and 12.

Fig. 9: A complete bony talocalcaneal bridge, drawn from John Hunter's specimen of bilateral complete talocalcaneal bridge in the Hunterian Museum of the Royal College of Surgeons of England[4]. Fig. 1-D, upper view, illustrates an example of this type.

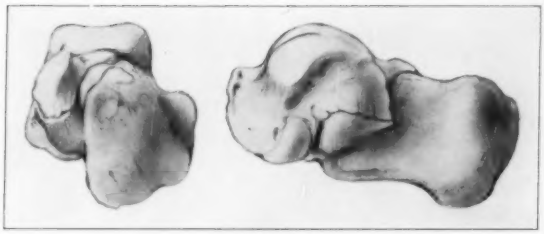

FIG. 10

Fig. 10: Drawing of a nearly complete talocalcaneal bridge. A bone mass from the medial side of the body of the talus is intimately fused by fibrous tissue (syndesmosis) or cartilage (synchondrosis) to a similar mass springing from the posterior margin of the sustentaculum tali. Figs. 4-A and 4-B show roentgenograms of such a case. (Drawn from a specimen from the Department of Anatomy, University of Toronto, Toronto, Ontario, Canada.)

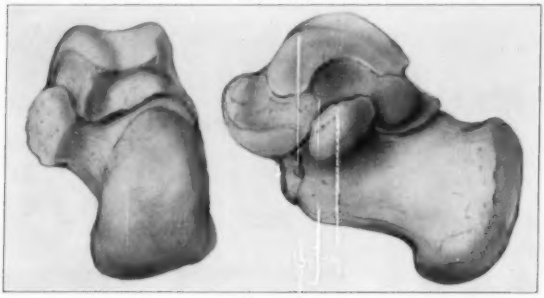

FIG. 11

Fig. 11: Drawing of a rudimentary talocalcaneal bridge. No part of this mass originates from the talus; it originates from the sustentaculum. It is placed in such a way that it acts as a bone block to inversion of the calcaneus under the talus. This is the more common type of incomplete talocalcaneal bridge acting as a bone block. Figs. 6-A and 6-B show such an anomaly.

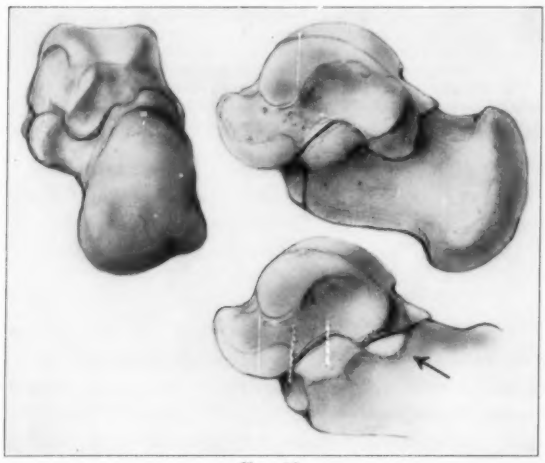

FIG. 12

Fig. 12: Drawing of the less common type of incomplete talocalcaneal bridge. The bone mass springs from the talus and overlaps the subtalar joint behind the sustentaculum tali, forming a mortise into which fit the superior and medial surfaces of the body of the calcaneus. When the bone block is removed, an articular surface is revealed between it and the medial surface of the body of the calcaneus (arrow). Figs. 7-A and 7-B show roentgenograms of this type of case.

Clinical examination reveals deformity in varying degree. Some patients in this group with incomplete talocalcaneal bridge may have no deformity or trifling deformity; others may have moderate or even marked valgus of the heel and mid-tarsal joint. In general the deformity is less severe in this group than in those patients in whom there is a complete talocalcaneal bridge. Movement at the subtalar joint is limited but not completely absent. Peroneal spasm may be present, especially in those patients whose symptoms follow injury. It varies in intensity, is least marked when the foot has been rested, and is intensified when the foot is in vigorous use.

Roentgenographic changes are important. The primary feature, a visible talocalcaneal bridge, of course, is absent. However, secondary changes are present. These are lipping of the superior margin of the head of the talus, narrowing of the talocalcaneal joint space and, in the lateral projection, blurring in the region of the joint between the sustentaculum tali and the neck of the talus. It should be emphasized that these secondary changes revealed by the roentgenogram are less marked in the type of case described in this paper than in those cases in which the talocalcaneal bridge is complete. Indeed, in some cases the talonavicular lipping may be negligible or absent. This is to be expected, since the incomplete lesion limits but does not completely obliterate movement in the

FIG. 13

Roentgenogram of the right foot of a man, thirty-nine years old, who presented clinical evidence of a rigid valgus foot. He had had two episodes of disability due to pain, each precipitated by injury. Both times these subsided with rest. There was an interval of many years between attacks. Apart from these two episodes his disability was not great, consisting only in a rigid foot with slight valgus of the heel. The roentgenogram showed an incomplete posterior talocalcaneal bridge (probably syndesmosis or synchondrosis) at the site of the os trigonum.

subtalar joint and hence distorts movement in the talonavicular joint much less severely. Lipping at the superior margin of the talonavicular joint, if present, is strong confirmatory evidence of the presence of a talocalcaneal bridge, but its absence does not necessarily exclude the possibility of this anomaly, especially in the incomplete form we are here describing.

OPERATIVE TREATMENT OF TALOCALCANEAL BRIDGE

This paper is concerned with the nature and cause of rigid valgus foot. It is planned to discuss treatment in a later publication. Nevertheless, it seems appropriate to say something here of operative treatment. Severe deformity, even though it is painless, may be a justification for operation, but the most important indication for operative treatment is persistent pain in addition to deformity. Patients with incomplete talocalcaneal bridge may have no pain until they are subjected to trauma. They may recover from the painful state and often do. Operative treatment, therefore, should be reserved for cases of persistent disability due to pain or to severe deformity, especially if it is accompanied by persistent pain.

We have had no success to date in operative attempts to restore movement in the subtalar joint by resection of the talocalcaneal bridge or of the block of bone impeding movement. If the bridge is complete or nearly so, the development of the subtalar joint has been so impaired that it is incapable of normal function. The same is true to a lesser degree in patients with an incomplete bridge. Therefore, operation should not be undertaken for the restoration of movement but should be reserved for the relief of disabling pain or the correction of deformity. This can best be accomplished by subtalar fusion. It should be recognized that pain may arise from wear-and-tear changes in the talonavicular

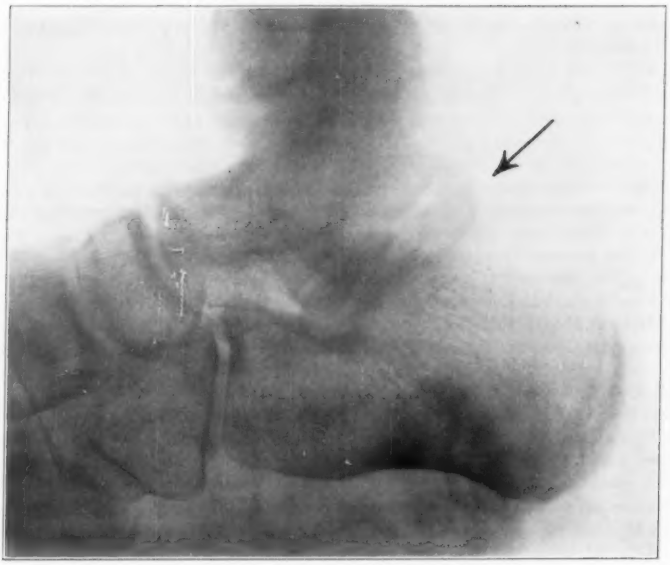

FIG. 14

Roentgenogram showing a case of trigonal talocalcaneal bridge in a twelve-year-old boy who had the lesion in both feet. (Courtesy of Dr. A. R. Shands, Jr., Wilmington, Delaware.)

joint. In fact, when the talocalcaneal bridge is complete and movement in the subtalar joint is entirely absent, it is only in the talonavicular joint that pain can arise. Consequently, if pain is sufficiently severe to justify operative treatment, an assessment of the talonavicular joint must be made, and fusion of this joint must be added to that of the subtalar joint, if indicated. A medial approach is best, since it permits the lesion to be visualized.

SUMMARY

1. A further report is made upon the problem of rigid valgus foot due to talocalcaneal bridge, supplementing the original report in 1948[3].

2. A group of cases has been identified in which the bone anomaly is incomplete and does not reveal itself directly by x-ray. In many cases characteristic secondary roentgenographic changes in the talonavicular joint are present and the heel is fixed in valgus.

3. So far, all such cases explored by operation have revealed themselves to be due to the existence either of the calcaneal or of the talar element of a talocalcaneal bridge. In either case the bone mass limits movement by acting as a bone block.

4. Operative treatment of rigid valgus foot should be limited to the relief of disabling pain and the correction of severe deformity. It should consist in subtalar fusion through a medial approach, supplemented by talonavicular fusion when necessary.

ADDENDUM

While this paper was in preparation, a type of rigid valgus foot new to us came to our attention. It was due to fusion of the posterior end of the talus to the calcaneus, apparently by fusion of an os trigonum to both bones (Fig. 13). At about the same time the contribution of Outland and Murphy, in 1953, on tarsal anomalies and rigid flat feet appeared in the first number of *Clinical Orthopaedics*. In this the authors recorded two similar cases of talocalcaneal bridging by means of the os trigonum. Finally, at the June 1953 meeting of The American Orthopaedic Association at which this paper was read, Dr. A. R. Shands, Jr., called our at-

tention to two similar cases of posterior talocalcaneal fusion through the medium of the os trigonum. With his permission we reproduce a roentgenogram of one of these cases (Fig. 14).

It seems evident from these observations that there is an additional type of talocalcaneal bridge which may cause rigid valgus foot resulting from fusion of the os trigonum to the posterior ends of the talus and calcaneus.

REFERENCES

1. Badgley, C. E.: Coalition of the Calcaneus and the Navicular. Arch. Surg., **15:** 75–88, 1927.
2. Grice, D. S.: An Extra-Articular Arthrodesis of the Subastragalar Joint for Correction of Paralytic Flat Feet in Children. J. Bone and Joint Surg., **34-A:** 927–940, Oct. 1952.
3. Harris, R. I., and Beath, Thomas: Etiology of Peroneal Spastic Flat Foot. J. Bone and Joint Surg., **30-B:** 624–634, Nov. 1948.
4. Harris, R. I., and Beath, Thomas: John Hunter's Specimen of Talocalcaneal Bridge. J. Bone and Joint Surg., **32-B:** 203, May 1950.
5. National Research Council: Canadian Army Foot Survey. Ed. 2 (abridged). Ottawa, Ontario, Canada, 1952.
6. Outland, Tom, and Murphy, I. D.: Relation of Tarsal Anomalies to Spastic and Rigid Flat Feet. Clin. Orthop., **1:** 217–224, 1953.
7. Shands, A. R., Jr., and Wentz, I. J.: Congenital Anomalies, Accessory Bones, and Osteochondritis in the Feet of 850 Children. Surg. Clin. North America, **33:** 1643–1666, 1953.
8. Pfitzner, W.: Beiträge zur Kenntnis des menschlichen Extremitätenskelets. VII. Die Variationen im Aufbau des Fussskelets. Schwalbes Morphol. Arbeiten, **6:** 245–275, 1896.
9. Slomann, H. C.: On Coalitio Calcaneo-Navicularis. J. Orthop. Surg., **3:** 586–602, Nov. 1921.

DISCUSSION

Dr. M. Beckett Howorth, New York, N. Y.: Pfitzner, in 1896, described nine anatomical specimens, two from his own material and seven from the literature, with partial or complete bridging from the talus medially to the sustentaculum tali. The principal variations consisted in a fibrous band, an accessory joint, or a bony bridge. He attributed the bridging to an accessory bone, the os sustentaculi, sometimes united to the sustentaculum, sometimes to the talus, at other times free, or united to both. He also described fifteen specimens of calcaneonavicular bridging and collected thirty-eight cases from the literature. The significance of these observations escaped the clinician until Dr. Harris, in performing subtalar arthrodesis for rigid flat-foot through a medial incision, recognized this bridging at operation. Harris and Beath, in 1948, reported twelve cases of this bridging, demonstrated the anomaly roentgenographically, and called attention to the association of lipping of the talar head superiorly, and sometimes lipping of the navicular. This was the definitive paper and should be read by all interested in the subject. The present report is supplementary and deals with the lesser degrees of the anomaly, which are not easily recognized in the roentgenogram. The pathological findings at operation are particularly interesting.

Dr. Harris asked why the anomaly results in a valgus deformity. The answer is probably in growth. The accessory element pushes the calcaneus into valgus as it grows, in somewhat the same manner in which a growing hemivertebra deforms the spine.

It would be unwise to conclude that peroneal spastic valgus is always due to a tarsal anomaly or to rheumatoid arthritis. I have seen one case which occurred in tarsal tuberculosis. I have also seen several patients with unilateral peroneal spasm of marked degree completely relieved with conservative treatment and followed for many months. Some of these cases were due to trauma, others to a transient, non-specific tarsal synovitis. One might, of course, postulate that these patients had a mild, unrecognized bridging and that they might eventually again have symptoms, but this may be going too far. Moreover, we should be cautious in considering an arthrodesis until the diagnosis has been established and until the severity and duration of the pain and disability fully justify it. It appears to me that the lesser degrees of bridging between the sustentaculum tali and the talus can usually be seen by careful study in a good lateral roentgenogram. I agree with Dr. Harris that an arthrodesis is preferable to an attempt to excise the excess bone and restore motion. However, the three joints of the hind part of the foot act as one and I would certainly do a triple, rather than a simple, subtalar arthrodesis, as I think a better result would be assured.

Prof. Bryan McFarland, Liverpool, England: I wish to support Dr. Harris's contention that congenital anomalies of the foot are rarely isolated and operation may well fail if it is directed only to the obvious defect. I use the calcaneonavicular bridge as an example. The first stage of the condition may show an accessory os calcis and sometimes an os trigonum; the shape of the talus may show changes. One of my own

patients showed the stage in which there is nearly a bar projecting from the calcaneus, and there is already a joint between the bar and the navicular. It is at that stage that the complaint of pain commences, usually, as Dr. Harris has said, at adolescence or somewhat earlier. The third stage shows fusion by a complete bridge from the calcaneus to the navicular. [Roentgenograms illustrating these three stages were shown.]

In all three stages changes in the neck and head of the talus are evident: the arc of the head of the talus is incomplete, the neck is slender, and the subtalar joint is ill-formed. Limitation of rotation is not surprising, and it is interesting that this limitation is a prominent feature when there is a talocalcaneal bridge. An inference which is almost inescapable is that a congenital abnormality may progress from stage to stage; the "precalcaneal ossicle" becomes a bar and leads to synchondrosis, and the synchondrosis goes on to synostosis. There is no doubt about the second step; proof of the first is obviously difficult. The talocalcaneal bridge, to which Dr. Harris has drawn our attention, may well be part of, or comparable with, these changes and I wonder whether this will explain why removal of a calcaneonavicular bridge does not produce rotation movement of the foot. Perhaps, as so often happens in congenital defects, what the x-rays show is not the whole defect and it may be that if one insists on operating on calcaneonavicular bridges (I personally do not) one of the causes of failure to obtain movement is the presence of a "Harris bridge".

Dr. Carl E. Badgley, Ann Arbor, Michigan: In 1927 I published what, as far as I know, was the first paper on treatment of coalition in the calcaneonavicular joint. Slomann, in 1921, had called attention to the fact that this congenital anomaly had been observed clinically. I presented the paper because, at that time, spastic flat-foot was regarded by the orthopaedic profession to be the result of a neurogenic factor and it was believed that it could be treated by lengthening of the peroneal tendon, by manipulation under anaesthesia, and by application of a plaster cast. These measures were not successful in some cases and I felt that I had failed in not being able to obtain the results of my masters.

I saw changes which I called a "beak" on the talus; the changes resembled those of arthritis. I knew that triple arthrodesis was the procedure recommended for arthritis. I therefore operated upon those feet which had not responded to conservative treatment and found the typical calcaneal bar which has been so well demonstrated today by Prof. McFarland. This has been reported in the literature since 1865 by anatomists; it has been recorded by Pfitzner and others, and has become a well known anatomical structure. Dr. Harris in 1948 reported on the talocalcaneal condition.

Among the causes responsible for the condition is synostosis of the various tarsal bones. In certain cases there is failure of separation of the cartilaginous anlage of the tarsal bones; this is as much a cause of rigid flat-foot as the secondary tarsal bones reported by Pfitzner. I have examples of talocalcaneal coalition from our anatomical department which are the result of complete failure of separation of the cartilaginous anlage of the two bones. I mention this because it is important not to stress, as Dr. Harris says, an accessory bone as the causative factor. The point to be stressed in spastic, rigid flat-foot is that this is due to a pathological process which is produced by an abnormality in the mechanism of development of the joints.

The lesion is arthrogenic. There are several demonstrable etiological factors: (1) the accessory bones producing coalition; (2) abnormal growth changes; (3) arthritis, primary or secondary; (4) congenital failure of cleavage of the primary cartilage. The point I wish to make is that there is an abnormality of the articulations and that the cure of that condition is to get rid of those abnormal articulations by a triple arthrodesis.

GIANT-CELL TUMOR OF THE PATELLA

A Case Report

BY GORDON W. CAMERON, M.D., EDMONTON, ALBERTA, CANADA

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The patella is an uncommon location for giant-cell tumor. Twenty-three cases have been reported, the most recent having been reported by Lantzounis in 1947.

Roemer, in 1945, published a review of all the previously recorded cases, which had been diagnosed variously as "myeloid disease", "cystic endosteal myeloid sarcoma", "endosteal sarcoma", "myeloid sarcoma", "central giant-cell sarcoma", "giant-cell sarcoma", "primary sarcoma", "osteoclastoma", and "benign giant-cell tumor".

The ages of the patients varied from nineteen to forty-five years, the average age being thirty years. There have been fourteen female and nine male patients.

The treatment of choice has been either excision of the diseased portion of the bone or patellectomy. In only two cases was there recurrence and these patients were treated by curettage of the lesion.

A history of trauma has been reported in the majority of cases, including the present one. In Chatterjee's case, however, there was no history of predisposing injury.

The present case is that of a male Air Force sergeant, thirty-five years old, who was admitted to the University of Alberta Hospital on July 31, 1953, complaining of a painful right knee of eleven days' duration.

This man had sustained a fracture of the right patella, twenty-one months previously, as a result of a severe blow to the knee in an aircraft accident. At that time, he had been treated in a plaster cylinder for five weeks. The patient had first been seen in our Clinic five weeks after this injury.

Roentgenograms of the patella at that time had suggested a tumor. It was felt, however, that the roentgenographic findings were consistent with his injury, and the cast was removed. In retrospect, however, it is quite apparent that the tumor was present at that time. After six weeks of quadriceps exercises, the patient made a good functional recovery and returned to his full duty as a mechanic.

FIG. 1

FIG. 2

Fig. 1: Lateral view of knee after the fall, showing fracture through the osteolytic area of patella.

Fig. 2: Anteroposterior roentgenogram, showing expansion of the rarefied lesion approximately one year later.

Two months prior to his present injury, he had had some aching in his right knee following a route march, but otherwise he had had no discomfort.

On July 19, 1953, while walking downstairs, he slipped and, in a sudden attempt to regain his balance, he experienced a severe pain in the right knee cap.

Physical examination revealed a painful swollen right knee with moderate effusion and severe local patellar tenderness. Roentgenograms revealed a pathological fracture through a giant-cell tumor or a simple cyst of the patella (Figs. 1 and 2). The laboratory data were normal and not contributory.

On August 4, 1953, a patellectomy was done, and the pathological findings were as follows:

"The patella, measuring 6.5 by 5.0 by 3.5 centimeters, exhibits an area of softening, approximately two centimeters in diameter, on the lower portion of the articular surface [Fig. 3]. The articular cartilage in the softened area is irregularly pitted and furrowed and is a rust-brown color. The remaining articular cartilage is of normal color and consistency but is moderately fibrillated.

"The cut surface shows replacement of bone in the lower two thirds by soft friable tissue, predominately reddish brown in color, splotched with dark red and gray areas.

"Sections through the reddish-brown tissue toward the center of the patella show a moderately cellular stroma composed mainly of spindle-shaped cells, although in some areas their shape is more ovoid. A few of these cells contain a light-brown pigment. A fine collagenous intercellular material is noted throughout the stroma. Many giant cells are seen scattered throughout the vascular stroma. In some areas, the giant cells are somewhat more numerous than in others. They have abundant

FIG. 3

Photograph of articular surface of patella.

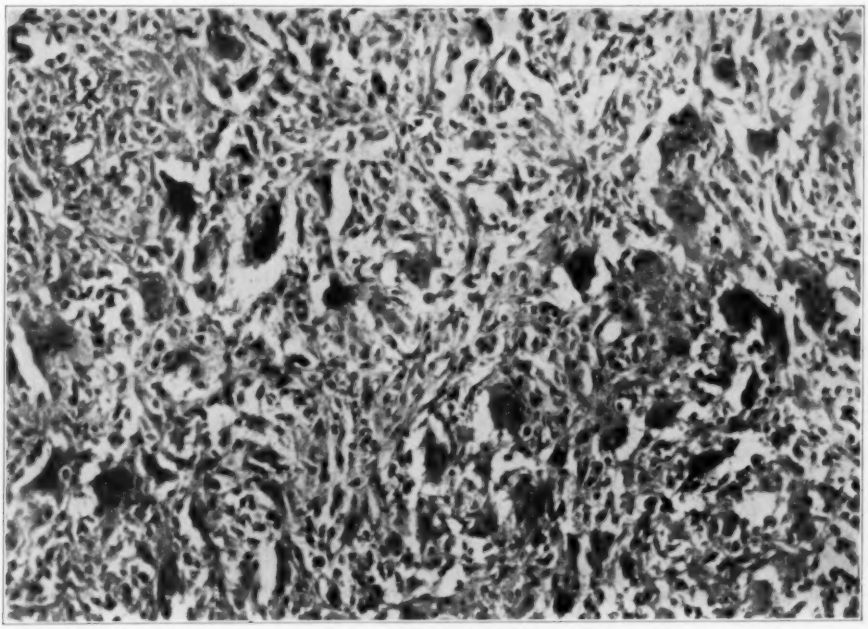

FIG. 4

Microscopic appearance (× 265).

eosinophilic granular cytoplasm. Their shape is ovoid, but many of the borders are poorly defined and tend to tail off into processes which blend with the intercellular stromal collagenous material.

"The nuclei of the giant cells are centrally located and are oval in shape. Each has a central nucleolus. The number of these nuclei varies from two or three to several dozen. These nuclei resemble the stromal nuclei. These are features of a giant-cell tumor of bone.

"According to Lichtenstein's classification[3], this is a Grade 1 tumor." (Fig. 4.)

A leg cylinder was applied at the time of operation, and the patient was encouraged to do straight-leg-raising exercises in the early postoperative period. He was discharged on the tenth postoperative day, walking with the aid of crutches. Four weeks after the operation, the cylinder was removed and the patient was given DeLorme exercises daily for six weeks.

Six months after operation, the patient had a full range of pain-free motion and no limp. No sign of recurrence was evident.

REFERENCES

1. Chatterjee, S. N.: Case Report: Osteoclastoma of Patella. British J. Radiol., **12**: 316–317, 1939.
2. Lantzounis, L. A.: Giant Cell Tumor of the Patella Treated by Resection. New York State J. Med., **47**: 1018–1020, 1947.
3. Lichtenstein, Louis: Bone Tumors. Vol. 1. St. Louis, The C. V. Mosby Company, 1952.
4. Roemer, F. J.: Benign Giant Cell Tumor of the Patella. Am. J. Surg., **67**: 563–566, 1945.

GIANT-CELL TUMOR OF THE SIXTH CERVICAL VERTEBRA

Report of a Case

BY HAROLD S. BOWMAN, M.D., AND WILLIAM J. REALS, M.D., WICHITA, KANSAS

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Relatively few cases of giant-cell tumor in the vertebrae have been reported in the literature. The reported occurrences, where documented fully, were found for the most part in the lumbar vertebrae or in the sacrum. The appearance of a proved giant-cell tumor in the sixth cervical spinous process has led us to present the clinical features of a single case, together with treatment and a brief review of the literature.

Coley, citing Lewis, reported one cervical giant-cell tumor, as did MacFarlane and Linell. The tumor reported by the latter authors was located in the third cervical vertebra. Numerous other reviews [2,4,7,9,10,12] of giant-cell tumors report rare examples of these neoplasms in the vertebrae, but the majority do not give the exact anatomical location. The infrequency of mention of cervical giant-cell tumors leads to the conclusion that the tumor occurs only rarely in this area of the spine.

The histogenesis of this tumor has been presented in several excellent reviews [11, 12]. Many authors refer to these growths as osteoclastomata. The question of whether these lesions are benign or malignant tumors remains a problem not yet fully solved by oncologists. It has been pointed out by Geschickter and Copeland that the tumor in the spine most commonly involves the neural arch or its appendages. The present case exhibits this characteristic location; the tumor was considered a benign lesion.

E. O., a white woman, eighteen years old, was admitted to the Wichita-St. Joseph Hospital on November 5, 1950. For the five or six weeks prior to admission the patient had noted soreness in the muscles of her neck which seemed to be made much worse by movement. The week prior to admission the pain had become more pronounced in the lower part of the back of the neck. Movement of the left arm caused a "catching" sensation medial to the right scapula. She had been perfectly well except for these complaints. The past history and family history were not contributory.

Physical Examination

The essential physical findings were confined to the posterior part of the neck. Pressure over the sixth cervical spinous process elicited local discomfort of a dull type. There was moderate loss of motion in the neck due to soreness. The remainder of the physical examination was entirely normal.

The laboratory examination, which included serological studies and urinalysis, was negative. Blood count revealed 4,340,000 red blood cells, with hemoglobin of 11.5 grams per 100 cubic centimeters of blood, and 8,450 white blood cells with a normal differential count.

A roentgenogram of the chest was negative.

The roentgenologist * reported a destructive lesion in the spinous process of the sixth cervical vertebra, associated with a fracture in the mid-portion (Fig. 1). No evidence of bone proliferation could be seen. Possible diagnoses which were considered included giant-cell tumor, lymphoma, and granuloma of the bone.

On November 6, 1950, the patient was taken to surgery, and under general anaesthesia a five-centimeter incision was made over the sixth cervical spinous process. Dissection was carried down about the process which was found to be fractured at its mid-portion. A small amount of red meatlike material was removed from the interior of the base of the process. The process and a portion of the adjacent lamina were removed. Convalescence was uneventful.

Pathological Examination

The gross material consisted of irregular fragments of bone, measuring up to 2.5 by 2.5 centimeters, and portions of soft dark red-yellow tissue which were of irregular outline and measured two centimeters in diameter. These tissues were soft, but were not otherwise remarkable; when they were cut, they seemed to have the consistency of fibrous tissue.

Microscopic Examination

The soft tissue was composed of striated muscle and masses of oedematous fibrous tissue. Decalcified bone showed prominent trabeculae. The medullary cavity contained normal cellular material. Along one margin of the bone, however, a number of multinucleated giant cells, growing in a dense fibrous stroma, were seen. These cells infiltrated between the trabeculae and were also seen in and near the fracture line (Fig. 3).

FIG. 1

FIG. 2

Fig. 1: Roentgenogram of the cervical vertebrae, showing fracture of the spinous process at the sixth cervical vertebra, was made on admission.

Fig. 2: Roentgenogram made at follow-up examination, three years later.

* Bernard Halper, M.D.

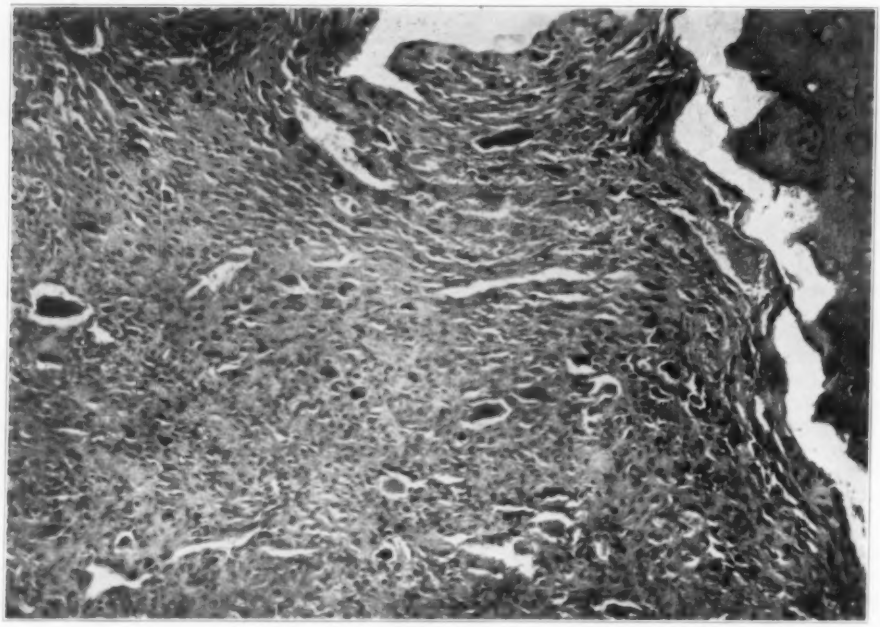

FIG. 3

Medium-power photomicrograph of tumor taken through the line of fracture at top (× 160).

The diagnosis of benign giant-cell tumor with pathological fracture of the sixth cervical spinous process was made.

Deep x-ray therapy was given following discharge from the Hospital. Treatment consisted of 1000 r to each of three ports over the posterior right and left lateral cervical areas.

The patient was last seen in October 1953. She had remained completely asymptomatic (Fig. 2).

The case, including the roentgenograms and pathological material, was reviewed by Dr. Dallas B. Phemister and Dr. C. Howard Hatcher, who concurred in the diagnosis of benign giant-cell tumor.

REFERENCES

1. COLEY, B. L.: Neoplasms of Bone. New York, Paul B. Hoeber, Inc., 1949.
2. ELLIS, FRANK: Treatment of Osteoclastoma by Radiation. J. Bone and Joint Surg., **31-B:** 268–280, May 1949.
3. GESCHICKTER, C. F., and COPELAND, M. M.: Tumors of Bone. Ed. 3. Philadelphia, J. B. Lippincott Co., 1949.
4. HAMSA, W. R., and CAMPBELL, L. S.: Giant-Cell Tumor of the Spine. A Report of Two Cases. J. Bone and Joint Surg., **35-A:** 476–478, Apr. 1953.
5. HATCHER, C. H.: Personal communication, 1953.
6. MACFARLANE, J. A., and LINELL, E. A.: Benign Giant-Cell Tumour of Third Cervical Vertebra: A Case Report. British J. Surg., **21:** 513–518, 1934.
7. MEYERDING, H. W.: Treatment of Benign Giant-Cell Tumors by Resection or Excision and Bone Grafting. J. Bone and Joint Surg., **27:** 196–206, Apr. 1945.
8. PHEMISTER, D. B.: Personal communication, 1950.
9. PROSSOR, T. M.: Treatment of Giant-Cell Tumours of Bone. With a Review of Twenty-Five Cases. J. Bone and Joint Surg., **31-B:** 241–251, May 1949.
10. STEWART, M. J., and RICHARDSON, T. R.: Giant-Cell Tumor of Bone. J. Bone and Joint Surg., **34-A:** 372–386, Apr. 1952.
11. WILLIS, R. A.: The Pathology of Osteoclastoma or Giant-Cell Tumour of Bone. J. Bone and Joint Surg., **31-B:** 236–240, May 1949.
12. WINDEYER, B. W., and WOODYATT, P. B.: Osteoclastoma. A Study of Thirty-eight Cases. J. Bone and Joint Surg., **31-B:** 252–267, May 1949.

HEADACHE AS THE FIRST AND ONLY SIGN OF BASILAR IMPRESSION*

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During the course of a study concerning the cause and treatment of severe intractable headache in the occipital area, it was found that an unusual number of the cases severe enough to warrant operation showed pathological lesions in and about the atlanto-occipital area. In fact, more than one third of the cases which came to surgery had had some type of organic disorder in this region. Five of these patients had had platybasia or basilar impression without neurological symptoms other than headache. Since in most of the cases described in the textbooks there seem to have been long tract signs, nystagmus, vertigo, and other outstanding neurological signs, it seemed appropriate to search the literature to see whether or not other authors had found cases of platybasia and basilar impression represented only by occipital pain.

Poppen, Ammerman, and Holden described two cases (their Cases 9 and 10) in which the outstanding complaint was headache aggravated by coughing and sneezing and by extending the head. In each case, the neurological examination was negative. In Case 3 of their series, the patient had had headache with weakness and dizziness. In Case 6, the patient had had headaches for ten years and had become incapacitated by them. In all of these cases, which must be considered as having been seen early, since no severe neurological signs had developed, the results of the operation were fair to satisfactory. In other cases in the same series, in which more serious neurological findings were present, and in still other reports in the literature, the results of surgery, while sometimes brilliant, were often disappointing.

Many of those who have studied this subject have pointed out the urgency of discovering platybasia in its incipient stages. O'Connell and Turner stated that early diagnosis is important, since operative treatment should be undertaken as early as possible. Poppen and his coworkers declared that patients with symptomatic basilar impression should be operated on early and that the medulla and upper cervical cord should be adequately decompressed. Both Chamberlain and Lichtenstein noted the appearance of syringomyelia and hydromyelia in cases of platybasia. This is probably the result of degeneration of the spinal cord due to long compression by the bone anomaly. To quote O'Connell and Turner: "The results of the surgical treatment of basilar impression are considerably influenced by the length of the time interval between the onset of symptoms, due to the deformity, and their attempted relief by surgery."

Basilar impression is an invagination of the foramen magnum of the skull about the upper end of the spine in such a manner that the atlas is forced upward into the rim of the foramen magnum. The odontoid process is forced against the junction of the medulla and the spinal cord, and the bony ring of the atlas compresses the medulla. Over a period of years, severe and often irrevocable damage is done.

In the past, the condition has been thought to be difficult to diagnose. It has had to be differentiated from multiple sclerosis, amyotrophic lateral sclerosis, syringomyelia, Arnold-Chiari deformity, and tumor of the posterior fossa. Eight of ten of Scoville and Sherman's cases were diagnosed over long periods of time as multiple sclerosis or syringomyelia. Chamberlain, however, established a line by roentgenogram from the posterior tip of the hard palate to the posterior internal rim of the foramen magnum. If the upper limit of the odontoid process extends above this line, basilar impression is likely. Incontrovertible evidence is obtained at the time of operation, when, by direct visualization, the arch of the atlas is noted to be within the circle of the foramen magnum.

Surgical treatment was first undertaken by Olivecrona in 1934 with removal of a portion of the posterior arch of the foramen magnum; some good results were obtained

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even in advanced cases. Since that time, various workers have reported series of from one to ten cases. As Scoville and Sherman have pointed out, platybasia is more prevalent than is common'y known.

The author has had cases other than those reported here which have had, in addition to headache, more outstanding neurological symptoms; however, in every case known to him, headache has been a prominent part of the patient's history. O'Connell and Turner reported neck pain in all five of their cases and headache in four of five. Mayerszky's patient had a headache in the vertex, most marked in the morning, for one and a half years. In the case reported by Bagley and Smith, occipital pain developed after the patient had attempted to jump to a moving truck. It should be pointed out here that many authors have remarked about the fact that the onset of symptoms has followed a head injury or a neck injury.

Our series of five cases is presented here in the hope that emphasis on the occipital pain as an early symptom may bring more of these cases to operation before irrevocable neurological deficit has appeared.

CASE REPORTS *

Case 1. J.W.B., a female of fifty-five years, gave occipital headache as her chief complaint. She also complained of slight dizziness which was described as being "a swimming of the head". The headache was worse upon rotation of the head or when the head was carried in a fixed position for a long period of time, as in watching television. On examination, it was noted that she carried her head tilted slightly to the right. There was a question of whether or not there was some hypo-algesia over the first division of the trigeminal nerve on the left. Otherwise, the patient's neurological examination was completely negative.

When conservative treatment had failed, the patient was subjected to a high cervical posterior rhizotomy for the intractable occipital pain. During the course of the operation, the arch of the atlas was noticed to be well within the rim of the foramen magnum, as in basilar impression. In addition, there was a fusion of the atlas to the skull. It was also found that the spinal nerve roots in the upper cervical area ran upward, and an Arnold-Chiari malformation,—that is, a herniation of the cerebellar tonsils through the foramen magnum into the cervical spine—was discovered. The second cervical sensory root was found to be densely adherent to the dentate ligament. It had a devitalized appearance. In this case, the second cervical sensory root was cut bilaterally and a decompression of the foramen magnum was done. When she was last seen, one year after operation, the patient's headaches were considerably improved. Occasionally, she complained of the same dizziness as before operation. All in all, however, she felt that the operation had been most worth while.

Fig. 1

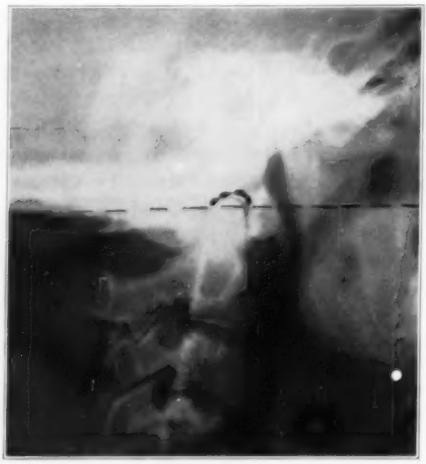

Fig. 2

* Cases 1, 3, and 5 have also been reported in another article, "X-Ray Demonstrable Lesions in Occipital Headache", published in the *Journal of The Medical Association of Georgia*, **43**: 871–874, Oct. 1954.

FIG. 3

FIG. 4

CASE 2. M.J., a white female, twenty-five years old, complained of severe occipital pain of three years' duration accompanied by a tickling, burning dysaesthesia in the suboccipital area which radiated into the parietal area on the left. It was worse upon hyperextension of the neck. The pain had begun soon after an accident in which she had caught her hair in an electric drill and received a severe blow on the head. The neurological examination was almost completely negative. There was tenderness over the occipital nerve, and some hypo-algesia over the posterior parietal area of the scalp and in the dermatome of the second cervical nerve. Operation was undertaken and a high cervical posterior rhizotomy was done. Roentgenographic examination (Fig. 1) had been suggestive of basilar impression, and, at operation, this condition was encountered. A suboccipital decompression and division of the posterior roots of the second and third cervical nerves on the left were done. One year after operation, the patient reported that she felt like a new person and was very grateful for the surgery.

CASE 3. J.L.C. was a twenty-year-old male who had had excruciating occipital headache for two or three months. It radiated into the vertex and into the right temporal area and was sometimes present on the left also. The neurological examination was completely negative. The roentgenograms suggested basilar impression (Fig. 2). On operation, he was found to have a severe degree of basilar impression. There was also fusion of the atlas to the skull. There were many arachnoid adhesions. In this case, no suboccipital decompression was done, but a cervical rhizotomy of the sensory roots of the second and third cervical nerves was performed bilaterally. Two years after operation, the patient reported complete relief.

CASE 4. A.B.C., a female, thirty-six years old, had had occipital headache radiating to the vertex for ten years. Examination showed tenderness to pressure over the occipital nerve, with pain radiating to the bridge of the nose; otherwise, the neurological examination was negative. Roentgenograms (Fig. 3) showed fusion of the second cervical vertebra to the third. Basilar impression was suspected. On operation, the arch of the atlas was found to be lying completely within the rim of the foramen magnum. No suboccipital decompression was done, but the sensory roots of the second and third cervical nerves were divided bilaterally. Eight months after operation, the patient was still quite uncomfortable.

CASE 5. L.L.B., white male, forty-four years old, had been suffering from progressively severe occipital headaches for ten years, the pain radiating to the vertex. There was tenderness in the suboccipital area, and novocain injection gave considerable relief. Otherwise, the neurological examination was negative. Operation showed a definite basilar impression in spite of the fact that roentgenograms (Fig. 4) had not suggested it. No suboccipital decompression was done, but a posterior rhizotomy of the second and third cervical nerves was accomplished bilaterally. Two years later, the patient reported little relief.

In two of the three cases showing basilar impression in which sensory rhizotomy of the second and third cervical nerves was done but the decompression at the foramen magnum was not carried out, practically no relief was obtained, suggesting that there is a source of pain other than the high cervical nerves.

SUMMARY

In five cases of basilar impression proved by roentgenogram and operation, the first and practically the only symptom was severe, intractable occipital headache. In three of these cases there was almost total relief of pain, and in two cases, in which the suboccipital decompression was not done in spite of the presence of basilar impression, little relief was obtained. It is suggested that in cases of severe occipital headache, roentgenographic search for the possibility of basilar impression is advisable.

ADDENDUM: Since this paper was written, three more cases of basilar impression have been discovered, with headache as the presenting symptom.

REFERENCES

1. BAGLEY, CHARLES, JR., and SMITH, G. W.: Unilateral Cervical Displacement of Cerebellum Associated with Basilar Impression, Producing Signs of High Cervical Cord Tumor. Ann. Surg., **133:** 874–885, 1951.
2. CHAMBERLAIN, W. E.: Basilar Impression (Platybasia). A Bizarre Developmental Anomaly of the Occipital Bone and Upper Cervical Spine with Striking and Misleading Neurologic Manifestations. Yale J. Biol., **11:** 487–496, 1939.
3. LICHTENSTEIN, B. W.: Cervical Syringomyelia-like States Associated with Arnold-Chiari Deformity and Platybasia. Arch. Neurol. and Psychiat., **49:** 881–894, 1943.
4. MAYERSZKY, CLARA: Platybasia: with Case Report. J. Neurol., Neurosurg., and Psychiat., **12:** 61–65, 1949.
5. O'CONNELL, J. E. A., and TURNER, J. W. A.: Basilar Impression of the Skull. Brain, **73:** 405–426, 1950.
6. POPPEN, J. L.; AMMERMAN, H. H.; and HOLDEN, G. O.: Basilar Impression (Platybasia). Surg. Clin. North America, **33:** 847–855, 1953.
7. SCOVILLE, W. B., and SHERMAN, I. J.: Platybasia. Report of Ten Cases with Comments on Familial Tendency, a Special Diagnostic Sign, and the End Results of Operation. Ann. Surg., **133:** 496–502, 1951.

DISCUSSION

EXPERIENCES WITH THE PALMER OPEN REDUCTION OF FRACTURES OF THE CALCANEUS

(Continued from page 155)

The authors emphatically stated that no single patient who had had the Palmer operation had normal talocalcaneal motion at follow-up, and yet over 30 per cent. had no symptoms referable to this limited function of the joint. One cannot help wondering if some of these ratings will not have to be changed because of the development later of degenerative arthritis in the talocalcaneal joint.

For a small group of cases, the authors are to be congratulated on their excellent results.

DR. MAXFIELD (closing): I appreciate the comments in the discussion, and I would like to say one word about the few patients who have had fractures with extreme comminution. Fortunately, contrary to the expectations of those who have not looked into these joints, the articular surface itself is usually not comminuted to any extent. The comminution is lower down in the bone. One patient of our series of twenty did have considerable comminution of the articular surface; he did not go back to his regular work for thirty months, and the result was not considered to be satisfactory. The incidence of comminution of the articular surface is one in twenty in our experience. The other nineteen fractures could be restored to essentially normal positions. Technically, I think that, with experience, we can improve our results with this procedure. I appreciate Dr. Edmunds' suggestion about early mobilization, and we also have considered doing this, because it appears that these fractures heal very rapidly and that the mobilization could be started earlier.

I want to say, in closing, a few words about traumatic arthritis in these patients. Of course, we do not know yet what a ten-year or fifteen-year follow-up will disclose in these cases. All I can say is that I believe that none of the results in our patients has changed materially after about a six-month period,—that is, in general, the result is the same at three years (and in one case, at forty-four months) as it was at six months.

SIMPLE TRANSVERSE OSTEOTOMY AND THREADED-PIN FIXATION FOR CONTROLLED CORRECTION OF TORSION DEFORMITIES OF THE TIBIA

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AND EDWARD A. EVANS, M.D., SALT LAKE CITY, UTAH

Derotation osteotomy of the tibia is performed frequently for severe medial torsion of the tibia, associated with some cases of talipes equinovarus, poliomyelitis, congenital torsion of the tibia, as well as in spastic paralysis. Several operations have been devised for the correction of medial torsion of the tibia in children, but none has proved entirely satisfactory in the hands of the authors. The procedure to be described in this paper avoids some of the major drawbacks of existing methods of osteotomy of the tibia and is characterized by its simplicity of execution. The authors have used the method successfully in twelve patients with medial torsion of the tibia. All of the patients were less than five years of age, and the deformities were associated with club-foot or were idiopathic in nature.

The simplest and probably the oldest operation for the correction of medial torsion deformity in children is a transverse osteotomy of the tibia made a safe distance below the proximal epiphyseal plate. The distal tibial fragment can then be rotated on the proximal fragment, thus permitting correction of the deformity. Unfortunately, it is difficult to control the corrected position by means of a long cast if the knee is permitted to remain in extension. If, on the other hand, the knee is placed in flexion of 45 degrees, loss of the correction may be prevented by maintaining the neutral position of the upper fragment; however, there is now added another danger, — namely, the great likelihood of angular deformity occurring at the site of the osteotomy. It will also be difficult to judge the exact amount of correction obtained, especially in small children, when the extremity is placed in a cast in this position.

In an attempt to overcome these difficulties, O'Donoghue devised what he has called a "controlled rotation osteotomy" of the tibia. This consists in a Z-type osteotomy in the proximal portion of the tibia and the removal of a longitudinal segment of the medial cortex of sufficient width to permit lateral rotation of the distal tibial fragment into a corrected position. This act of rotation closes, at the same time, the longitudinal gap left by the removal of the strip of cortex, and the fragments are held approximated by chromic catgut sutures placed through drill holes in the bone.

Although this procedure has been widely adopted, it has certain disadvantages: for example, the osteotomy is complicated and difficult, and it requires a long incision, the use of the motor saw, and also a wide stripping of the periosteum. Removal of a lengthy and wide piece of cortical bone decreases the size of the tibia and correspondingly weakens it, particularly in small children.

The authors' procedure, in turn, represents an attempt to avoid the postoperative fixation problems of the simple transverse osteotomy procedure, as well as the difficulties of the Z-type operation just mentioned. The procedure consists, in brief, in a transverse osteotomy made in the proximal portion of the tibia and subsequent fixation in the corrected position of the distal and proximal fragments by means of two threaded pins, one through the upper fragment and one through the lower fragment. Both pins — and, therefore, both tibial fragments — are kept in fixed alignment by means of C clamps which are, in turn, incorporated in a loosely fitting long plaster cast (Fig. 1).

SURGICAL TECHNIQUE

A tourniquet is applied on the thigh, and the limb is prepared and draped. The leg is placed first in a neutral position with the patella pointing toward the ceiling. A

threaded pin, gauge 0.094 inch, is next drilled transversely through the tibia, about five centimeters distal to the proximal epiphyseal plate. Following this, the leg is rotated later-

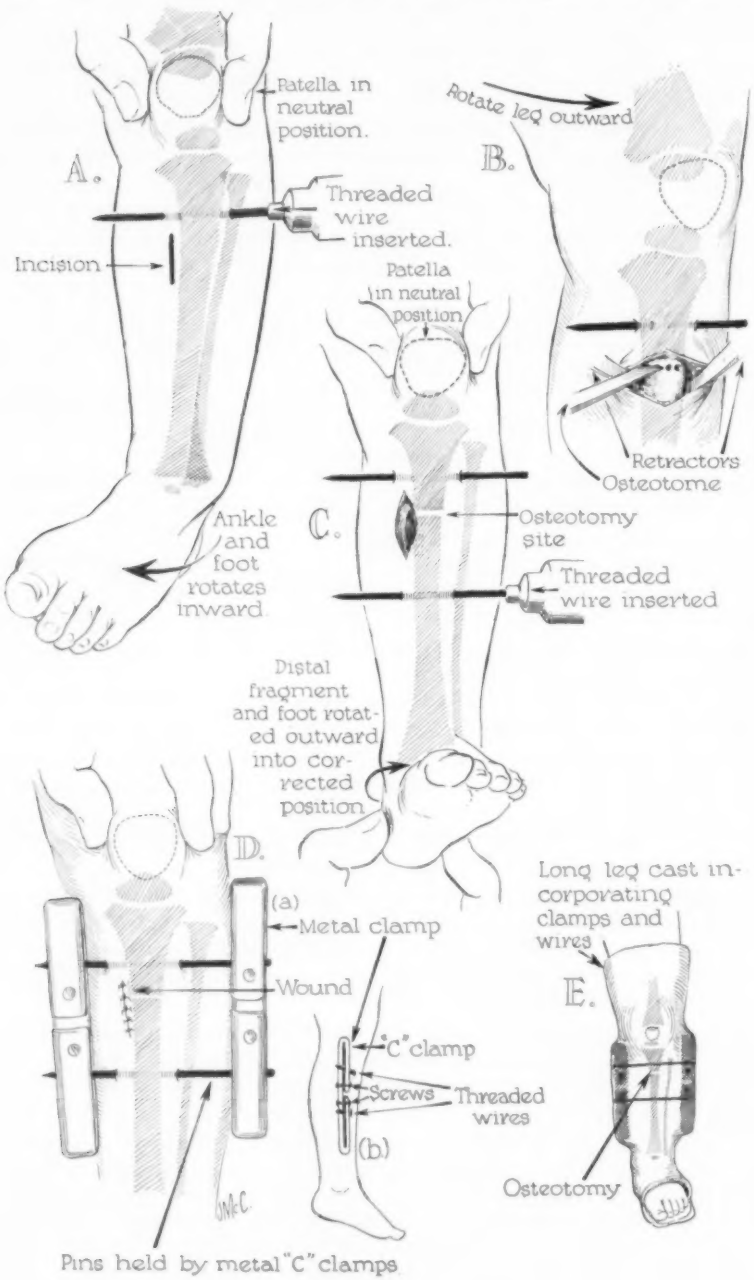

FIG. 1

Artist's sketch showing the successive steps in performing derotation osteotomy of the tibia with threaded-pin fixation.

ally, in order to facilitate the making of the skin incision, five centimeters long, over the medial surface of the tibia just below the inserted pin. The tibia is exposed subperiosteally and multiple holes are drilled through the bone at the level intended for the osteotomy. The soft tissues are protected by means of curved periosteal elevators as the bone is divided with a thin osteotome.

The knee is again placed in a neutral position, and the distal tibial fragment and the foot are rotated outward into the corrected position. A second threaded pin, running parallel to the first, is inserted transversely through the distal fragment of the tibia at a point five centimeters distal to the osteotomy. Two metal clamps (C clamps), which are placed over the protruding ends of the pins on each side of the leg, securely maintain the tibial fragments in alignment. The wound is now closed and a long cast which incorporates both wires and metal clamps is applied over sheet wadding.

The patient is able to leave the hospital twenty-four to forty-eight hours after the operation. The parents are instructed to watch the circulation in the child's toes and to report at once any change from the normal. However, there has not as yet been a single instance of swelling of the foot or of other circulatory embarrassment, for the casts have been made to fit loosely. Roentgenograms are made just prior to discharge from the hospital and are repeated two weeks later. Healing of the osteotomy usually is complete in eight to ten weeks, at which time the cast is discarded and the threaded pins are removed.

The C clamps can be made in any brace shop from ten-inch strips of flat iron stock, three-fourths of an inch wide, or from half-roll aluminum. The clamp measures five inches in length, while the two short arms of the C are each two and a half inches long. The open space between the front and back of the clamp, into which the ends of the threaded pins are fitted, measures three-sixteenths of an inch. Screws are placed five-eighths of an inch from the free ends of the two short arms of the C. When the screws are tightened, the threaded pins are held securely by the viselike grip of the clamp.

Full correction of the deformities without performing an osteotomy of the fibula has been obtained in all of the twelve cases treated by the authors. Leaving the fibula intact, moreover, affords additional support for the osteotomized tibia and prevents anterior-posterior angulation. The fact that the pins are completely threaded instead of being smooth is believed to give added protection against the occurrence of infection along the pin tract.

O'Donoghue, D. H.: Controlled Rotation Osteotomy of the Tibia. Southern Med. J., **33**: 1145–1148, 1940.

MONOSTOTIC FIBROUS DYSPLASIA OF THE METACARPAL

A Case Report

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The group of bone lesions known for many years in the literature as osteitis fibrosa has been divided by the students of osseous pathology into several separate and distinct entities. One of these is the solitary bone cyst known as monostotic fibrous dysplasia.

FIG. 1

Preoperative roentgenogram.

This lesion usually occurs at a single site in the metaphyseal end of the long bones of healthy children and is not accompanied by systemic, metabolic, endocrine, or other skeletal changes. For these reasons it should not be confused with von Recklinghausen's disease or with Albright's disease. Both of these conditions usually produce multiple bone lesions. The latter is also known as polyostotic fibrous dysplasia.

Credit for clarifying the classification of cystic disease of the skeleton may be given mainly to Albright for his description in 1937 of the syndrome, which was later given his name, and to Lichtenstein [3,4] and Jaffe [4], who in 1942 pointed out clearly that the monostotic variety can be considered a separate entity. Geschickter and Copeland, in their textbook, provide a comprehensive historical review and refer with due credit to the work of Schlumberger, who in 1946 reviewed sixty-seven cases of monostotic fibrous dysplasia. In no instance did the lesion occur in the small bones of the hands or feet.

The following case is reported with the intention of recording the occurrence of a lesion which proved to be monostotic fibrous dysplasia involving the second metacarpal.

CASE REPORT

An eight-year-old white boy was admitted to the Hospital on April 17, 1950, with the chief complaint of a "lump" on the back of the right hand. The child and his parents described the mass as having been present for about eighteen months. It had been growing slowly, but no local symptoms had occurred and there was no history of limitation of function. He was right-handed. About one year previously, he had been admitted to this Hospital on another service and a biopsy specimen had been taken. There had been an uneventful interval since the surgery. Review of the previous record revealed that the biopsy had been reported as fibro-ostosis of bone.

Review of symptoms and the past medical history revealed no record of diseases with possible lasting sequelae.

Physical examination revealed a well developed, well nourished white boy. On the dorsum of the right hand, overlying the second metacarpal, a mass was seen to arise about two centimeters above the normal surface of the back of the hand. It was largest at about the middle of the metacarpal and could be felt to be continuous proximally and distally with the second metacarpal bone. It did not involve the second

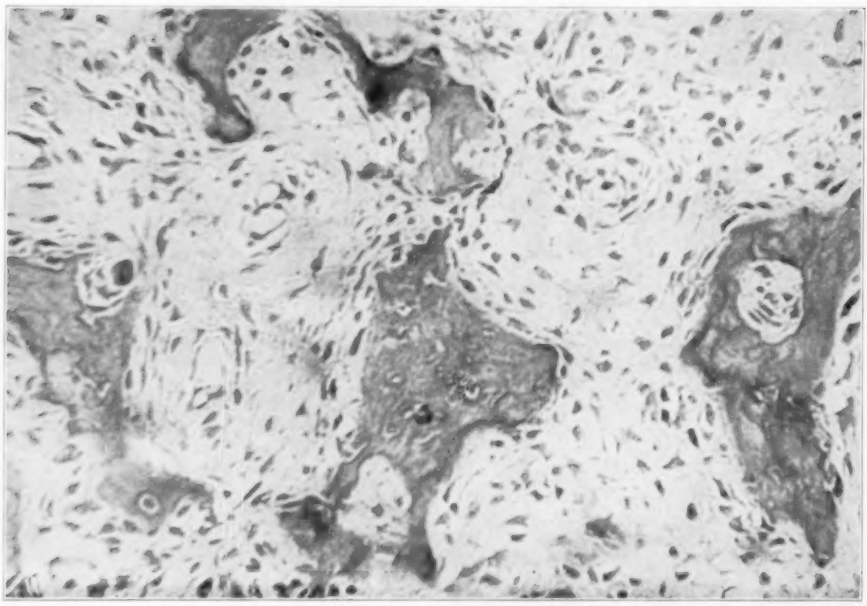

FIG. 2

Photomicrograph (× 135) of tissue from the tumor, showing new and degenerative bone spicules interspaced with bundles and whorls of connective tissue.

FIG. 3

FIG. 4

Fig. 3: Roentgenogram made two months after excision of the tumor and replacement with tibial-bone graft.

Fig. 4: One year after surgery.

FIG. 5

Three years and six months after the operation.

FIG. 6

FIG. 7

Figs. 6 and 7: Photographs of the hand made three years and six months after surgery. Surgical scar can be seen. No limitation of function is detectable.

metacarpophalangeal joint nor did it extend into the wrist. It was about two centimeters wide at its largest diameter. A longitudinal well healed scar was present on the dorsum of the hand.

The skin over the mass was freely movable, of normal color and temperature, with no dilated veins present. The tendons and subcutaneous tissues were not fixed to the smooth, bony-hard surface of the tumor. The range of motion of all joints of the hand and wrist was complete, and no sensory changes could be detected. There were no palpable lymph glands and no enlargement of the spleen or liver.

At admission urinalysis, hemoglobin, and white-blood-cell count were within normal limits. Serological tests, serum phosphorous, calcium, and phosphatase were also normal. The sedimentation rate was not elevated and tuberculin tests were negative. Roentgenograms revealed the presence of a bone tumor involving the entire right second metacarpal with the exception of the distal epiphysis. Roentgenograms of the entire skeletal system were made and no other lesions were discovered. The mass had a smooth outline and was opaque, dense, and mottled throughout (Fig. 1). The diagnosis of a benign, expanding tumor of the right second metacarpal, probably monostotic fibrous dysplasia, was made.

On April 27, 1950, with the boy under general anaesthesia and with a pneumatic tourniquet in place, a dorsal longitudinal incision of 7.6 centimeters was made directly over the mass. It was found that the extensor tendon to the index finger had been pushed radially by the tumor. The periosteum of the bone was incised and stripped easily from the entire circumference of the enlarged metacarpal. The mass was found to be smooth and hard with a pale surface, but the cortex could be punctured easily with a blunt instrument. Expansion had occurred mainly in a dorsal direction, although some enlargement in the radial and ulnar directions had taken place. The distal epiphysis was not involved. The entire metacarpal proximal to the epiphysis had been replaced by the lesion.

An osteotomy was performed just proximal to the distal epiphysis and the bone was disarticulated at the carpals. The mass was thus removed in its entirety, but the periosteum was left in place.

A tibial graft was then taken and formed to fit into the defect. The distal end was pointed and was driven into the epiphysis of the remaining distal segment. The periosteal tube was sutured about the graft and the remaining tissues were closed.

A plaster-of-Paris cast was applied with the fingers in extension.

The specimen removed by surgery was five centimeters in length and was about 2.5 centimeters in diameter at its greatest expansion. At the distal or osteotomized end there were five millimeters of normal-appearing bone. The enlarged proximal end was covered with normal-appearing cartilage. The surface of the tumor was smooth, hard, and white. When the specimen had been split lengthwise, the cortex was seen

as a very thin shell. The entire medullary cavity had been replaced by a firm, somewhat resilient, whitish tissue which occupied the entire bone to the distal 0.5 centimeter, where there was an abrupt transition to normal bone.

Microscopically, the entire tumor consisted mainly of bundles and whorls of connective tissue with highly vascular, interlacing, disorganized spicules of new and degenerative bone (Fig. 2). Occasionally, near the area of transition to normal bone, areas were seen where there had been apparent new-bone formation, with new and poorly calcified bone spicules present. A rare giant cell or osteoclast was seen, and many of the spicules were lined with osteoblasts. The microscopic picture was, in all respects, characteristic of fibrous dysplasia of bone.

The postoperative course was uneventful, and the patient was discharged two weeks later, wearing a short cast extending to the metacarpophalangeal joints. Follow-up roentgenograms (Fig. 3) revealed the graft to be in good condition two months after surgery. At examination after one year (Fig. 4), excellent union between the graft and the distal fragment of the metacarpal could be seen, as well as a reduction in the opacity of the graft. At two years, no remarkable changes had occurred; function of the hand and wrist was unimpaired.

Upon examining the roentgenogram made three years and six months after the operation (Fig. 5), it was difficult at first glance for one to determine the site of the surgery. At this time, the second right metacarpal was more dense than the others and was slightly irregular along its shaft and at its proximal articulation. The epiphysis had closed. The shaft of the bone had begun to assume the appearance of its adjacent fellow, with a suggestion of marrow cavity and cortex.

During the entire postoperative course and in the interval during which the roentgenograms shown were made, there was no clinical disability or loss of function. Clinically, the hand appeared to be normal, except for the presence of the operative scar (Figs. 6 and 7).

DISCUSSION

The remarkable behavior of the tibial graft which was used to replace all but the distal 0.5 centimeter of the second metacarpal deserves comment. After two months, the graft appeared in the roentgenograms (Fig. 3) as a dense shadow with almost parallel sides. The final roentgenogram seemed to indicate that the patient had been provided with a new metacarpal bone.

The law of Wolff states that every change in the static relations of a bone leads not only to a corresponding change of internal structure, but also to a change of external form and physiological function. Without much doubt, the changes we have observed in the grafted site qualify in these three respects. Since the graft had been seated into the intact periosteal tube of the shaft of the excised bone and had the same muscle attachments, the same stresses and strains may have been exerted upon it as upon the original bone.

The base of the second metacarpal receives on its dorsal surface the insertions of the extensor carpi radialis longus and part of the extensor carpi radialis brevis. At the base on the volar surface, there is found the insertion of the flexor carpi radialis, and it also provides the origin of the fasciculi of the oblique adductor pollicis.

The effect of these muscles on the structure of the new metacarpal, which we must assume replaced the graft, could not have been so great, however, as that of the two dorsal and one volar interosseus muscles which attach to the shaft of the bone along much of its length.

The tibial graft was of both cortical and cancellous type, and there remains no doubt that it was vascularized and replaced by healthy new bone.

The treatment of lesions of the phalanges and metacarpals by the use of homogenous transplantation of whole bones from the foot to the hand and by metacarpals and phalanges from frozen-whole-cadaver banks is being investigated in other parts of the world. This is a radical departure from the technique of using tibial or iliac grafts, which are expected to be followed by vascularization and replacement. In Pedemonte's series of thirteen cases, four of the replaced bones were metacarpals. In three of these cases, the bone replaced was the first metacarpal and good results were reported. To date, no surgery of this type has been reported in North America.

REFERENCES

1. Albright, Fuller; Butler, A. M.; Hampton, A. O.; and Smith, Patricia: Syndrome Characterized by Osteitis Fibrosa Disseminata, Areas of Pigmentation and Endocrine Dysfunction, with Precocious Puberty in Females. New England J. Med., **216:** 727–746, 1937.
2. Geschickter, C. F., and Copeland, M. M.: Tumors of Bone. Ed. 3, pp. 283–287. Philadelphia, J. B. Lippincott Company, 1949.
3. Lichtenstein, Louis: Polyostotic Fibrous Dysplasia. Arch. Surg., **36:** 874–898, 1938.
4. Lichtenstein, Louis, and Jaffe, H. L.: Fibrous Dysplasia of Bone. A Condition Affecting One, Several or Many Bones, the Graver Cases of Which May Present Abnormal Pigmentation of Skin, Premature Sexual Development, Hyperthyroidism or Still Other Extra-Skeletal Abnormalities. Arch. Pathol., **33:** 777–816, 1942.
5. Pedemonte, P. V.: Banco de falanges y metacarpianos. Su utilidad practica. Homotrasplantes de pequeños y de grandes huesos enteros. An. Ortop. Traumat., **4:** 231–236, 1951.
6. Schlumberger, H. G.: Fibrous Dysplasia of Single Bones (Monostotic Fibrous Dysplasia). Mil. Surg., **99:** 504–527, 1946.

SURGICAL CUTTING INSTRUMENTS TIPPED WITH TUNGSTEN CARBIDE

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Tungsten carbide came into being in 1896 when the French chemist, Henri Moissan, produced the metal while attempting to manufacture diamonds in his laboratory.[3]

With the results of Moissan's experiments in mind, Krupp scientists, during World War I, produced tungsten carbide. They cemented crushed particles of the metal with softer cobalt to form a compound which was successfully used to make tools almost as hard as diamonds, although the cost of producing them was prohibitive.

Motivated by the exigencies of World War II, American ingenuity conceived means to develop tungsten-carbide tips for machine tools at only a fraction of the cost of the Krupp tools.

Since World War II, this metal has made the jet age possible. Metallurgists now extrude the combination of tungsten, carbon, and cobalt powders in many shapes, and, in the final process, these "metal cookies" are baked to allow the cobalt to melt around the minute tungsten-carbide particles. From the resulting metal, the finished tool tips are made.

It is a simple procedure for any machinist to braze or to silver-solder the tungsten-carbide tips to all kinds of cutting tools.

For one year and a half, the author has used surgical cutting instruments tipped with this metal (Fig. 1). After having been autoclaved hundreds of times, these instruments have retained their snarp cutting edge.

DISCUSSION

It is a well established fact that autoclaving at 269 degrees Fahrenheit is the best way to sterilize instruments, although the cutting edge of ordinary instruments is dulled by the oxidation which occurs during this process.

However, instruments tipped with tungsten carbide may be autoclaved hundreds of times with no evidence of dulling and, with ordinary use, seldom need sharpening.

Tungsten carbide is almost diamond-hard, and like the diamond, is also quite brittle. For this reason, it is inadvisable to grind the cutting blade down to a fine-feather edge (Fig. 2, *A*) as these thin edges will chip when the instrument is dropped or when they come into contact with other instruments in transport. In making instruments from tungsten carbide,

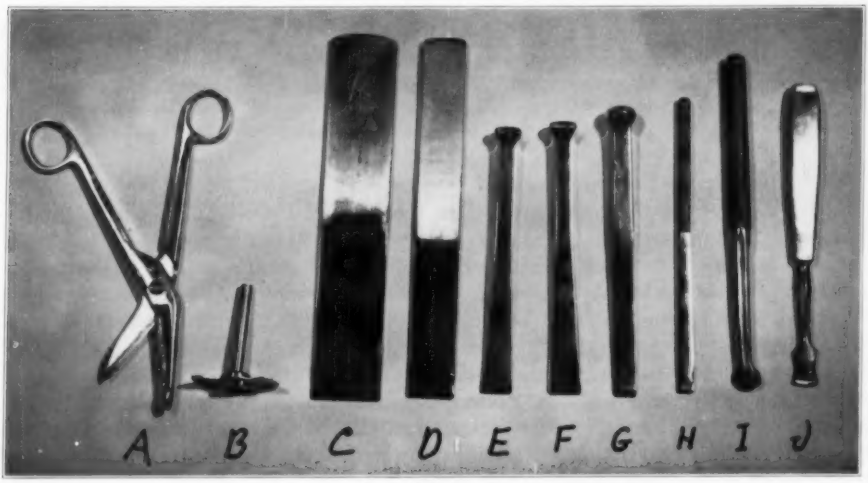

FIG. 1

A, Lister bandage scissors; *B*, electric saw blade; *C*, *D*, and *E*, osteotomes; *F*, *G*, and *H*, chisels; *I*, and *J*, periosteal elevators.

one should keep in mind that they must be ground with a short bevel (Fig. 2, *B*).

When necessary, tungsten-carbide tools are easily sharpened by means of an electric grindstone with an inexpensive, 180-grit, silicon-carbide wheel or a 220-grit diamond wheel. After being sharpened, these tools need no honing.

CONCLUSIONS

Tools tipped with tungsten carbide have the following advantages:

1. They can be produced at a nominal cost by any good machinist;

2. They can be autoclaved, thus ensuring quicker and more thorough sterilization;

3. They retain their cutting edge for years without being sharpened;

4. They can be sharpened on an inexpensive, readily obtainable, silicon-carbide grinding wheel; they need no honing.

However, they do have the disadvantage of chipping easily if they are ground to a fine-feather edge. If they are properly ground, the tools will not chip unless they are dropped or are grossly mishandled.

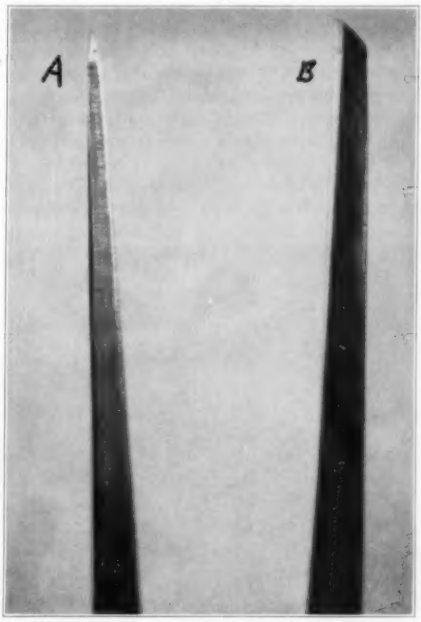

FIG. 2

A: The undesirable long beveled edge.
B: The correctly ground short beveled edge.

REFERENCES

1. LECKEY, W. C.: Tip Your Tools with Carbide. Part I. Popular Mechanics, **98:** 204–209, Sept. 1952.
2. LECKEY, W. C.: Tip Your Tools with Carbide. Part II. Popular Mechanics, **98:** 210–215, Oct. 1952.
3. MATCH, RICHARD: The Hardest Metals Made by Man. Popular Science, **164:** 158–162, 280, 282, March 1954.

THE HYDRAULIC LIFT FOR DECUBITUS ULCERS

Report of a Case

BY JACOB L. RUDD, M.D., BOSTON, MASSACHUSETTS

The hydraulic lift with an overhead crane raises a patient off the bed and into a chair. Various types of these lifts are on the market and the advantages listed by the various manufacturers suggest their use in lifting a patient from bed to chair, from chair to automobile, from chair to tub, and for various other purposes.

Such a lift has been found useful in the prevention and treatment of decubitus ulcers. Its value for such treatment was found in the case of a man in whom a decubitus ulcer was already present and was growing larger. A special type of bed which could be used to eliminate or even effectively diminish pressure on the back and heels of the patient with hip and leg fractures could not be found. It was difficult to retain a nurse or aide who could turn the patient frequently enough so that tissue breakdown could be prevented. The sacral decubitus ulcer was so extensive that the surgical consultant advised plastic surgery as the only treatment, as soon as the patient's general condition would permit.

CASE REPORT

A pedestrian, seventy-eight years old, was knocked down by an auto. He was immediately brought to a city hospital, where it was found that he had sustained four fractures of the pelvis (a comminuted fracture of the right wing of the ilium extending almost to the acetabulum with some separation of fragments, transverse fractures of both ischia, and a fracture of the left pubic bone). A week later, he complained of some pain in his right leg, and roentgenograms were made. They showed three fractures of the leg; both malleoli were fractured and there was a transverse fracture of the fibula.

The application of a firm wide pelvic band did not relieve his pelvic pain, but it did cause wrinkling of the skin, redness, and a beginning superficial loss of skin substance over the sacrum. This occurred within two weeks of his admission to the hospital. The sacral bone was believed to be superficially involved. Ulcers began to develop on the heels and over the greater trochanter also.

FIG. 1

FIG. 2

Fig. 1: Hydraulic lift used with overhead crane and slings supports patient so that the sacral ulcer is not in contact with bed.

Fig. 2: Hydraulic lift used with chair sling.

Special beds with separated wide bands of canvas or with separated sectional mattresses were not satisfactory, as the patient would sink between the canvas bands or the separated mattress sections and lie in a pool of moisture caused by the perspiration and detritus from the decomposing skin. In addition, the separated canvas bands and the sectional mattresses appeared to contribute to the pressure on the edges of the sacral ulcer, thus adding to the passive congestion of that area. A Stryker frame was tried, but it was so uncomfortable and ineffective in this particular case that its use was soon discontinued.

The Hydraulic Lift

After a month of treatment, a hydraulic lift with an overhead crane was secured. It had both wide and narrow canvas slings which could be adjusted to support the patient at points well above and below the decubitus ulcer over the sacrum. For long periods of time he could be raised high enough so that the sacrum and the heels did not rest on the bed (Fig. 1). The pressure was thus removed from the ulcerated area on the sacrum, as well as from the greater trochanters and the heels.

Many advantages were gained by the use of the overhead crane attached to the hydraulic lift. The body could be elevated so that the heels as well as the back were supported just above the bedclothes, thus permitting an easier approach to the ulcers for cleansing, ultraviolet irradiation, and bandaging. The patient could be elevated onto and removed from a bedpan. The frequent, necessary changes of soiled bed linen were easier. The patient could also be hoisted to the sitting position in the hydraulic lift. He was permitted to sit in it, well supported, or he could be lifted into a fairly comfortable chair in which there would be minimum or no pressure on the back and heels. In bed he could be turned on either side or could lie elevated in the supine or prone position on the canvas supports without any pressure on the already involved areas or the areas which were about to become involved. He soon learned to place his feet on the floor while his main weight was being supported by the lift. The early stages of walking were taught to this aged patient while he was supported by the overhead crane, and he gained confidence thereby. If he stumbled, he was held in an upright or sitting position so that he could not fall and injure himself.

COMMENT

An elderly patient, seventy-eight years old, was originally hospitalized for multiple fractures of the pelvis and right leg. After about two weeks, the main treatment problem concerned the sacral and heel decubitus ulcers. After about a month in the hospital, an overhead crane operated by the hydraulic lift was secured to help prevent further ulceration of the back and heels. The patient was soon able to sit up in the lift and to begin to do a little walking. The decubitus ulcers began to improve slowly, and there was gradual closing and healing. In about three months after the use of the hydraulic lift, the sacral decubitus ulcer cleared up completely without the extensive skin-grafting operation contemplated.

FIBULAR TRANSPLANT FOR LOSS OF SUBSTANCE OF TIBIA

Report of a Case *

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Methods of replacing a large amount of lost tibia by transfer of the fibula were referred to by Hahn and then by Codivilla, but it was Huntington who first described this operation in detail. Stone and Campbell have recommended other similar procedures. A case such as the following proves that the fibular transplantation is truly an excellent operation.

A clerk, twenty-seven years old, was admitted to the Hospital on October 2, 1951, complaining of inability to bear weight on his right leg because of loss of substance of the tibia. In 1944, he had sustained a compound fracture, resulting from a gunshot wound. Numerous débridements, followed by a sliding

FIG. 1

FIG. 2

FIG. 3

Fig. 1: Roentgenogram showing loss of substance of middle third of tibia, October 1951.

Fig. 2: Roentgenogram made in April 1952.

Fig. 3: Roentgenogram made in April 1953.

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FIG. 4 FIG. 5-A FIG. 5-B

Fig. 4: Fracture of transplanted fibula in May 1953.
Figs. 5-A and 5-B: Anteroposterior and lateral roentgenograms made in July 1954, showing condition of leg.

pedicle skin graft, had been required in order to obtain skin closure before definitive surgery could be done. An open reduction, in which some bone from the left tibia was used, had been performed late in 1945, but this procedure failed. Within six months another bone-grafting procedure, in which bone was taken from the right ilium, had been attempted. Infection developed subsequently, necessitating a number of sequestrectomies. The wound was allowed to heal by secondary intention.

Examination revealed that, over the entire anteromedial aspect of the leg, there was extensive scarring and thin, paper-like skin which was firmly adherent to the underlying soft structures. There was clinical evidence of a large loss of substance of the tibia, and only an intact fibula provided stability of the leg. Roentgenograms (Fig. 1) showed an absence of the middle third of the tibia and a healed fracture of the shaft of the fibula with posterior bowing. Sclerotic changes were present in the distal fragment.

Through a posterolateral incision, on October 5, 1951, the proximal end of the fibula was osteotomized and, after the contact surfaces had been freshened down to endosteal bone, it was secured to the lateral aspect of the proximal tibial fragment with screws (Fig. 2). No additional bone was used. The extremity was immobilized in a long cast.

On May 5, 1952, the distal fragment of the tibia was secured to the distal portion of the fibula with screws, and bone chips taken from the ilium were packed about the area through the same incision. The delay between the two operations could have been shortened, but the original plan had been to osteotomize the distal end of the fibula, also, during the second stage. Only while the actual procedure was being carried out, was the decision made not to do so. Immobilization was continued with a long cast until October 1952, when a below-the-knee cast with a walker was applied.

In April 1953, the cast was replaced by a calf-lift brace. On May 17, 1953, while descending a stairway, the patient fell and fractured this leg (Fig. 4). Again the extremity was immobilized in a long cast

until August 1953, when a below-the-knee cast and a walker were used; in October 1953, the same calf-lift brace was substituted. The roentgenograms made in July 1954 showed union between the tibia and fibula and marked hypertrophy of the transplanted fibula (Figs. 5-A and 5-B).

A review of the literature reveals that the procedure followed was actually that of Hahn, later modified by Codivilla, who, like Huntington, osteotomized the distal end of the fibula during the second stage in order to overcome the valgus deformity of the foot resulting from Hahn's operation. The deformity did not develop in this patient, because the fracture of the transplanted fibula one year after completion of the second stage corrected a mild valgus.

The procedure used in this case was the procedure of choice because of the inadequate skin on the anterior aspect of the leg. Replacement of the scar by a graft of whole-thickness skin would have been necessary if the usual anteromedial incision had been utilized. A method of fibular transplantation with a lateral incision overcomes the absolute necessity of having good skin over the anterior portion of the leg.

COMMENT

This case is presented in order to encourage the further use of this excellent operation, especially in patients in whom the defect in the tibia is large and the skin over the anterior aspect of the leg is poor. Only this procedure was successful after several had failed, including bone-grafting procedures which resulted in infection and deep scarring and required repeated débridements. It is obvious that the marked hypertrophy of the transplanted fibula graphically emphasized Wolff's postulate.

REFERENCES

1. Campbell, W. C.: Transference of the Fibula as an Adjunct to Free Bone Graft in Tibial Deficiency. Report of Three Cases. J. Orthop. Surg., **1**: 625–631, Oct. 1919.
2. Campbell's Operative Orthopedics. Edited by J. S. Speed and Hugh Smith. Ed. 2, Vol. I, p. 717. St. Louis, The C. V. Mosby Company, 1949.
3. Codivilla, A.: Quoted in Campbell's Operative Orthopedics.[2]
4. Hahn, F.: Quoted in Campbell's Operative Orthopedics.[2]
5. Huntington, T. W.: Case of Bone Transference. Use of a Segment of Fibula to Supply a Defect in the Tibia. Ann. Surg., **41**: 249–251, 1905.
6. Stone, J. S.: Partial Loss of the Tibia Replaced by Transfer of the Fibula, with Maintenance of Both Malleoli of the Ankle. Ann. Surg., **46**: 628–632, 1907.

Proceedings

THE RUSSELL A. HIBBS SOCIETY

The Meeting of The Russell A. Hibbs Society was held in Huntington, West Virginia, on April 30, 1954. Five formal papers were presented, as well as numerous problem cases. The Meeting was presided over by Dr. William McCracken of Huntington, West Virginia. Following the presentation of the papers, Dr. Felix Butte of Dallas, Texas, was elected President-Elect for the year 1955. The 1955 Meeting will be held in Dallas, Texas, on April 9, 1955.

Summaries of papers presented follow:

The Unknown in Orthopaedics. Dr. Albert Ferguson [1] read a philosophical paper in which he said that history demonstrates that the apparently proved truth of today is likely to be disproved in the future. Even the apparently obvious truth that the universe had a beginning, or that it did not have a beginning, is subject to doubt. We cannot conceive the beginning nor can we conceive the absence of a beginning. Since both sides of the proposition are beyond conception it is possible that the true statement is a third possibility which we cannot conceive — the unknown "X".

Medical dicta are less obviously true than the statement in the above illustration. They should, therefore, be more subject to doubt. This doubt is readily inserted in medical thinking. For example, if prolonged study has led us to believe that the cause of a certain condition must be either "A" or "B" because no other cause seems possible, we must still add the possible cause "X" — the unknown or not presently conceivable. Now it is no longer possible to conclude that the cause must be "B" because we can show that it is not "A". The "X" is always with us to keep our minds open to indications of possibilities not yet demonstrable.

Such open-mindedness can have highly practical results. In orthopaedics, for example, the consideration of physical factors not previously included as possible etiological agents has led to new and useful explanations of disease. Examples exist in fever as a cause of "congenital" malformations, defective remodeling instead of "growth" as a cause of exostosis, tensions produced by growth as the cause of several conditions including juvenile kyphosis and Osgood-Schlatter disease, and stimulation by motion as a cause of overdevelopment of cartilage to tumorous proportions.

Note: The usefulness of such ideas received unexpected emphasis in the "quiz" session which followed the presentation of this paper. Two of the cases were subject to a reasonable and clear explanation on the basis of stimulation of the development of cartilage by motion although confusion had previously existed due to conflict of clinical and histological evidence.

Roentgen Diagnosis of Chordoma. Dr. Albert L. Allen [2] reported that improved methods in roentgenography and more extensive use of roentgenograms contributed to the increased finding of chordoma and afforded greater efficiency in the preoperative diagnosis of this tumor. Thus, of late, there has been a higher reported incidence of chordoma than the 10 per cent. proved by roentgen diagnosis previously reported. Five new cases were recorded from an area with a population of 150,000 within a two-year period. Three of these were diagnosed outright by the roentgenologist or else were included in the differential diagnosis. Colored slides were presented to show the tumors as they were viewed clinically. The roentgenographic findings were presented.

The Management of Peripheral-Nerve Injuries. Dr. Thomas J. Holbrook [3] presented the essential diagnostic points for the recognition of palsies of the major peripheral nerves. The value of special electrodiagnostic tests and procedures in the recognition of nerve lesions, as well as their place in the assessment of recovery after nerve anastomosis, was discussed. These tests included muscle-nerve reactions to different electrical stimuli, the determination of chronaxia, and skin-resistance measurements. The times for nerve suture and the general techniques of nerve-end anastomosis and postoperative care were outlined.

The So-Called Codman Tumor. Dr. S. Werhammer [4] discussed the history of the so-called Codman tumor and described the pathology and histogenesis. Three cases, seen within two years, were reported. The first was in a thirteen-year-old boy with a chondroblastoma of the right humeral head. This case is considered to be typical of the disease as regards age, sex, symptomatology, roentgenographic findings,

[1] 1101 Beacon Street, Brookline, Massachusetts.
[2] Huntington, West Virginia.
[3] 955 4th Avenue, Huntington, West Virginia.
[4] St. Mary's Hospital, Huntington, West Virginia.

and pathological findings. The second case was in a man, forty-nine years old, with post-traumatic symptoms in the right knee joint of twenty-five years' duration. Tibial chondroblastoma, as well as a Charcot joint, was found. The third case was a woman, fifty-eight years old, with pain in the right knee of two years' duration. Roentgenographic findings disclosed a cystic tumor in the right tibial epiphysis and metaphysis. Pathological examination revealed a very cellular Codman tumor with possible malignant transformation. There was a difference of opinion as to the benignity or malignancy of this tumor among several pathologists. Critical evaluation of the three cases showed that two tumors occurred in patients forty-nine and fifty-eight years of age. No Codman tumors had previously been reported in this age group.

Treatment of Hematogenous Osteomyelitis. Dr. James A. Heckman [b] presented the current concepts of the treatment of acute hematogenous osteomyelitis and reported on thirteen patients treated during the past six years. The method of treatment employed was that of large doses of penicillin or other antibiotics, with incision and drainage of the soft-tissue abscess and general supportive measures. In no case was bone decompression resorted to. In this series of thirteen cases there were no deaths. One patient had metastatic lesions while the other twelve had complete healing of the bone lesion with no recurrence.

[b] 1032 6th Avenue, Huntington, West Virginia.

ACKNOWLEDGMENTS

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Acta Anaesthesiologica Belgica (Bruxelles), **5:** No. 1, 1954.
Acta Chirurgica Belgica (Bruxelles), **53:** Nos. 5, 6, 1954.
Acta Medicinae Okayama (Okayama, Japan), **8:** No. 4, 1954.
Anales del Servicio de Traumatología del Dr. López-Trigo (Valencia), **9:** Núm. 1, 1954.
Archiv für Japanische Chirurgie (Kyoto, Japan), **23:** Band, 2. Heft, 1954.
Archiva Medica Belgica (Bruxelles), **9:** Fasc. 2, 3, 4, 1954.
Boletin del Hospital Militar (Habana), **7:** No. 1, 1954.
Boletín del Instituto de Patología Médica (Madrid), **9:** Núm. 7, 1954.
Boletines de la Sociedad de Cirugía de Rosario (Rosario, Argentina), **21:** Nos. 3, 4, 5, 1954.
Boletines y Trabajos de la Sociedad Argentina de Ortopedia y Traumatologia (Buenos Aires), **29:** Nos. 3, 4, 5, 6, 1954.
Bollettino Bibliografico (Milano), **4:** 1/2, 1954.
Cirurgía, Ginecología y Urología (Madrid), **7:** Núm. 5, 1954.
The Crippled Child (Chicago), **32:** No. 3, 1954.
Hospital de Cirurgia, Boletim do Centro de Estudos (Aracaju, Sergipe, Brazil), **2:** No. 1, 1954.
Medica (Matanzas, Cuba), **12:** Núm. 5, 1953.
Medical Radiography and Photography (Eastman Kodak Company, Rochester, New York), **20:** No. 2, 1954.
Medicina Práctica (Zaragoza), Núm. 93, 1954.
The Nagoya Journal of Medical Science (Nagoya, Japan), **16:** No. 4, 1954.
Nagoya Medical Journal (Nagoya, Japan), **2:** No. 1, 1954.
P. B. Physicians' Bulletin (Lilly, Indianapolis), **19:** 9, 1954.
The Red Cross World (Geneva), **35:** No. 3, 1954.
Revista Médica Municipal (Rio de Janeiro), **18:** Núms. 1 e 2, 1953.
Yokohama Medical Bulletin (Yokohama), **4:** No. 6, 1953.

FREMONT A. CHANDLER

Word has been received of the sudden death of Dr. Fremont A. Chandler of Chicago on December 24, 1954. A more extended notice about Dr. Chandler will appear in a later issue of *The Journal.*

News Notes

The Twenty-second Annual Meeting of **The American Academy of Orthopaedic Surgeons,** under the presidency of Dr. T. Campbell Thompson of New York City, will be held at the Hotel Statler, Los Angeles, California, January 29 to February 3, 1955.

The 1955 Annual Meeting of **The American Orthopaedic Association** will be held at The Greenbrier, White Sulphur Springs, West Virginia, June 19 to 22.

The American Board of Orthopaedic Surgery has announced that examinations are to be held as follows:

Part II Examinations on January 27 and 28, 1955, at Los Angeles.

Part I Examinations at various locations in April 1955.

Applications should be made to the Secretary, Dr. Harold A. Sofield, 122 S. Michigan Avenue, Chicago 3, Illinois.

The Tenth Annual Meeting of the **American Society for Surgery of the Hand** will be held at the Biltmore Hotel, Los Angeles, California, on Friday, January 28, 1955. The preliminary program includes the following papers:

Tumors of the Hand.
Joseph L. Posch, M.D., Detroit, Michigan.

Tuberculosis of the Hand.
Philip H. Moore, M.D., Mt. Edgecumbe, Alaska (by invitation).

Providing Automatic Grasp by Flexor Tenodesis.
James N. Wilson, M.D., Los Angeles, California.

Congenital Subluxation of the Thumb into the Palm.
Elden C. Weckesser, M.D., Cleveland, Ohio.

Vasomotor Reactivity in Dupuytren's Contracture.
F. X. Paletta, M.D., St. Louis, Missouri (by invitation).

Surgery of Rheumatic Hands.
Sterling Bunnell, M.D., San Francisco, California.

Volkmann's Contracture.
J. Leonard Goldner, M.D., Durham, North Carolina.

Congenital Absence of the Radius.
Daniel C. Riordan, M.D., New Orleans, Louisiana.

Adduction Contracture of Thumb.
J. Edward Flynn, M.D., Boston, Massachusetts.

The Annual Meeting of the **Mid-Central States Orthopaedic Society** will be held at the St. Louis Medical Society Auditorium, St. Louis, Missouri, April 15 and 16, 1955. Headquarters of the Meeting will be at the Sheraton Hotel, St. Louis.

In order to stimulate interest and research in medical history among students of the medical schools of the United States and Canada, the American Association of the History of Medicine has established a medal named in honor of William Osler. **The William Osler Medal** will be granted annually to the author of the best student essay submitted to the Association. The essays should not exceed 10,000 words in length. Essays must be submitted before March 1, 1955, to Lloyd G. Stevenson, M.D., Faculty of Medicine, McGill University, 3640 University Street, Montreal, Canada.

The Third Congress of the **Sociedad Mexicana de Ortopedia y Traumatología** was held in Mexico City from November 14 to 20, 1954, under the presidency of Dr. Alejandro Velasco Zimbrón. Orthopaedic surgeons throughout Mexico attended this meeting. Short refresher courses were given by Dr. Hernández Ros-Codorniú (Spain), Prof. R. Merle d'Aubigné (France), Dr. Harold Boyd (the United States), Dr. Louis Lichtenstein (the United States), Dr. G. Alvárez F. (Mexico), Dr. M. Berúmen C. (Mexico), Dr.

B. Castro Villagrana (Mexico), Dr. A. García Amezcua (Mexico), Dr. R. Pérez Tamayo (Mexico), and Dr. A. Pérez Teuffer (Mexico). Honorary Presidents of the Congress were: Dr. Juan Farill, Dr. José Castro Villagrana, and Dr. A. Ortiz Tirado.

THE SIXTH WORLD CONGRESS OF THE INTERNATIONAL SOCIETY FOR THE WELFARE OF CRIPPLES

"Changing Attitudes in a Changing World" was the theme of the Sixth World Congress of the International Society for the Welfare of Cripples, which met at The Hague, the Netherlands, from September 13 through September 17, 1954. More than seven hundred delegates from thirty-six countries assembled to exchange information about techniques of treatment and services for the handicapped.

Dr. J. M. Ravesloot of the Netherlands presided at the Congress, which was held in cooperation with the Netherlands Central Society for the Welfare of the Disabled, the International Society affiliate in the Netherlands.

Sectional meetings devoted to medical, social, educational, and vocational services for the disabled were held. There were also sectional meetings on cerebral palsy, amputations, rheumatism and arthritis, and spinal paraplegia. Discussions of the organization of services and general sessions were parts of the formal program of the Congress. Various special groups met in conjunction with the major meeting.

Elections of officers and members of the Council were held, at which time Dr. Howard A. Rusk of New York was named President, succeeding Mr. Konrad Persson of Sweden. At the official dinner of the Congress, the first Albert Lasker Awards for distinguished international contributions to the welfare of the disabled were presented to Dr. Juan Farill of Mexico, Dr. Henry H. Kessler of New Jersey, and the Right Honorable Viscount Nuffield of England.

American physicians who presented papers at the Congress included, in addition to Dr. Rusk and Dr. Kessler, Dr. A. R. Shands, Jr., Dr. Meyer A. Perlstein, Dr. William T. Sanger, and Dr. Eugene J. Murphy. Physicians from England who addressed the Congress included Dr. Francis Bach, Dr. Ludwig Guttmann, Dr. C. J. S. O'Malley, Dr. John Craft, and Dr. A. G. Hardy. Dr. Keith S. Armstrong of Canada was a speaker.

Many other outstanding physicians from South America and Europe presented papers or led section meetings. Experts in related rehabilitation activities came from all over the world to participate in the Congress.

The Headquarters of the International Society for the Welfare of Cripples is located at 127 West 52nd Street, New York City. Mr. Donald V. Wilson is Secretary-General and Mr. Norman Acton is Assistant Secretary-General. Copies of the *Proceedings* of the Congress may be obtained from the Society's New York headquarters.

"Rehabilitation for Independence" was the theme of the Thirty-first National Convention of **The National Society for Crippled Children and Adults** which met in Boston from November 2 through 6, 1954. Fifteen hundred persons, including many orthopaedic surgeons, attended the convention, and orthopaedic surgeons were among the group of experts making contributions to the convention in the form of technical lectures.

The medical, social, vocational, and educational aspects of rehabilitation were discussed at the various general meetings and special seminars. Nationally known speakers who were present included Nelson A. Rockefeller, Undersecretary of the Department of Health, Education, and Welfare; Mrs. Ivy Baker Priest, Treasurer of the United States; Dr. Margaret Mead, noted anthropologist; Dr. William C. Menninger, world-famous psychiatrist; and Dr. William T. Sanger, President of the Medical College of Virginia.

Orthopaedic surgeons who spoke at the meetings included Dr. A. R. Shands, Jr., Medical Director of the Alfred I. duPont Institute; Dr. Allen F. Voshell, Professor of Orthopaedic Surgery at the University of Maryland; Dr. Charles O. Bechtol, Chief of the Division of Orthopaedic Surgery at Yale University; Dr. Eugene E. Record, Chief of the Amputation Clinic at Massachusetts General Hospital; Dr. Alexander P. Aitken, Medical Director of the Liberty Mutual Rehabilitation Center; Dr. William T. Green, Chief of the Orthopaedic Service at the Children's Medical Center in Boston; and Dr. Stanford Hartman, an orthopaedic surgeon from Phoenix, Arizona.

Special subjects that were given attention at the meeting included the use of braces, the problems of amputees, industrial back injuries, and other aspects of orthopaedic surgery as applied to rehabilitation.

The Fourteenth Japan Medical Congress will be held at Kyoto, April 1 to 5, 1955. The **Japanese Society of Orthopaedic Surgery** is one of the forty-one medical societies participating in this Congress. Meetings will take place at Kyoto University and Kyoto Prefectural Medical College. Additional information about the Congress may be obtained from the Secretary-General, Dr. Mitsuharu Goto, University Hospital, Medical Faculty of Kyoto University, Kyoto, Japan.

Book Reviews

SURGERY OF REPAIR AS RELATED TO HAND INJURIES. B. K. Rank, M.S. (Melbourne), F.R.C.S., F.R.A.C.S., and A. R. Wakefield, M.S. (Melbourne), F.R.C.S., F.R.A.C.S. Baltimore, The Williams & Wilkins Co. 1953. $8.00.

In the preface to this book, the authors state clearly and concisely their intentions in the recording of the subject matter. These can well be summarized by a direct quotation: "We have not set out to record in familiar fashion known fact, accepted opinions and methods of treatment under various arbitrary headings to which the title might well be dissected. Our object has been to record the more fruitful developments of personal opportunity unembarrassed by consideration of alternative procedures."

In the 250 pages which follow, one is aware of the truthfulness of the above statement. The two authors, highly skilled in plastic procedures and well exposed to contemporary knowledge of the art of hand reconstruction, set out to record their experience.

One, therefore, cannot be critical of limitations and instead must commend the other features of the text which in many ways are unique and perhaps less emphasized by others. Among these, for example, is the consideration of the viewpoint of the patient, which in our busy world is very apt to be subjugated, without intent, by the overwhelming enthusiasm arising from technical triumph.

The presentation of the surgical anatomy of the hand is done in such a painless way that the reader picks up the salient and practical points without the feeling of being temporarily plunged into an anatomical textbook.

The main emphasis of the text is given to primary treatment on the rightful assumption that adequate care and the obtaining of primary healing does much to lessen the need for later reconstruction. This section is well documented with specific cases, and many practical points relative to early treatment are divulged. Within this section the chapter on wound closure reflects the plastic skill of the authors. Since some of the procedures might prove a bit tedious or even risky, liberal use of the free skin graft is recommended for the uninitiated.

The remainder of the book deals with many other problems, such as unhealed wounds, burns, and late reconstruction. All described methods of treatment are sound in principle and apparently work well for the authors, even though they may lack the glamor of "new procedures". The short chapter on hand injuries in children brings out the salient points and provides opportunity to discuss the behavior of grafted tissue during growth.

Although it is in the province of the reviewer to pick out for criticism specific points which might deviate from his own views, to do so would accomplish little in a constructive way and would only serve to distract from the goodness of the whole. Thus, the book is heartily endorsed for all with serious interest in hand surgery, and its pleasant style, organization, and readability make it of especial value to those surgeons who of necessity must treat the injured hand along with their other daily tasks. The reader must not expect source book answers to all problems, but he will find much in the way of value and enjoyment.

L. D. Howard, Jr., M.D.

LES TUMEURS ARTICULAIRES MALIGNES. R. de Grailly et Henry Léger. Paris, Masson et Cie, 1952. fr. 600.

This is a study from the *Centre anticancéreux de Bordeaux* dealing mainly with malignant tumors of synovial origin, which American authors classify as synovial sarcomata.

The authors also describe briefly other types of tumors originating in the soft tissues of the joint. They point out the difficulties that may arise in the differential diagnosis.

Metastatic articular neoplasms and tumors from the neighboring structures invading the joint are dealt with in a further chapter.

Over half of this short monograph is concerned with history and a review of the world literature including references to cases of synovial sarcomata published in the last fifty years. The authors endeavor to trace the evolution of ideas concerning the pathogenesis of this type of tumor, the clinical and pathological features of which have been well described by Haagensen and Stout, Bennett, Pack, and Ariel.

Dr. Fritz Schajowicz

ATLAS OF ORTHOPEDIC TRACTION PROCEDURES. Carlo Scuderi, B.S., M.D., M.S., Ph.D. St. Louis, The C. V. Mosby Company, 1954. $12.50.

Dr. Scuderi has adequately filled a need in the orthopaedic literature with this profusely illustrated and concise *Atlas of Orthopedic Traction Procedures*. He has covered a wide variety of traction procedures without

becoming entangled in the ropes and pulleys of a subject which might easily have been treated in a more complex manner. It is more than a "picture book" of traction procedures; in it is discussed the necessary equipment, the indications, pitfalls, and principles of each type of traction.

There are over 125 excellent illustrations in this 230-page volume. It is well indexed and designed to serve as a complete working manual. In addition to his descriptions of specific traction procedures (both skeletal and skin), the author deals with such important subjects as the hospital bed, mattresses, overhead frames for orthopaedic traction, and the use of the Stryker frame.

There seem to be almost as many "wrinkles" in applying traction as there are individuals applying it and, although most agree on the basic principles of traction, many differ in just how these principles are to be carried out. Some readers, for example, will perhaps feel, upon reviewing the illustrations in Dr. Scuderi's book, that they would have "run this rope that way" or "put that pulley here". However, these minor differences of opinion do not in any way detract from this fine work, and it is recommended to every orthopaedic surgeon, nurse, and orderly who has to do with setting up and maintaining traction apparatus.

Thomas L. DeLorme, M.D.

DIE ENTWICKLUNGSSTÖRUNGEN DER EXTREMITÄTEN. A. Werthemann. (Handbuch der speziellen pathologischen Anatomie und Histologie, IX.Band: Bewegungsapparat, 6.Teil, von O. Lubarsch, F. Henke, und R. Rössle.) Berlin, Springer-Verlag, 1952. DM 98.

The monographs of pathological anatomy and histology which were initiated by Lubarsch and Henke in 1924 have, since their demise, been carried on by other outstanding pathologists. *Developmental Disturbances of The Extremities* is Part 6 of Volume IX in a series concerned with Motor Apparatus, and it is by A. Werthemann of Basel.

This monograph covers all the common skeletal variations and abnormalities. Each subject is classified taxonomically, is presented with complete embryological and pathological data, and is illustrated with pictures, roentgenograms, and line drawings. The book has two main parts:

Part I deals with the abnormalities of the skeletal anlage and is divided into two major sections. The first section is devoted to the various types and degrees of diplogenesis and retrogressions of the primordial extremities in great detail. The second section is concerned with descriptions of normal epiphyseal development and joint development, the various disturbances related thereto, congenital deformities and contractures, and various aplasias.

Part II covers malformations on the basis of disturbances in the primitive soft-tissue anlage including syndactyly, cleft hand and foot, and asymmetrical gigantism and dwarfism.

A bibliography of German, English, French, and Italian literature is appended to the discussion of each subject.

This publication, if revised in the light of the contributions of the two years since its publication, would make an admirable textbook; and if translated into English, it would find wide appreciation by the pathologist and the orthopaedist as a reference work.

Thomas F. Broderick, Jr., M.D.

EXCHANGE FELLOWSHIPS TO GREAT BRITAIN — 1955

The Committees on Exchange Fellowships of The American Orthopaedic Association and The Canadian Orthopaedic Association report that there has been a great interest on the part of young orthopaedic surgeons in the United States and Canada in this opportunity for travel and study in Great Britain. At the end of December they had received sixty-three applications from the United States and seven from Canada.

The Committees expect to announce their selection of the four candidates from the United States and the one candidate from Canada by the end of January 1955.

Tentative transatlantic bookings have been made to leave New York, April 20, on the Queen Elizabeth and to return to New York on the Queen Elizabeth, June 14, in time for the meetings of The American Orthopaedic Association at White Sulphur Springs and The Canadian Orthopaedic Association at the Seigniory Club, Quebec.

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All phases of rehabilitation center administration will be covered during the periods the trainees are at the Institute and, in addition, such topics as: chronic disease as a socio-medical problem, rehabilitation centers—history, types, organization, disciplines contributing to rehabilitation, coordination of services and community considerations. Trainees will be given specific work assignments during the training period.

STANDARDS FOR SELECTION OF TRAINEES:

Sex—Men or women will be accepted.

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Education—Bachelor's degree—minimum.

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Personality attributes—Trainees should possess such personality attributes as: feeling for leadership, personal stability, resourcefulness, tact, and effectiveness. If practicable, applicants may be given a personal interview by a rehabilitation center administrator before acceptance for the course.

Stipend—A stipend of $250 per month for the 7-month period will be paid to each trainee. Travel expense between New York City and the locations of on-the-job placement centers will be paid by the Institute. All other expenses will be borne by the trainee.

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1904–1905: Vol. II, Nos. 1, 2, 3, and 4; August, October 1904; January, April 1905.
1905–1906: Vol. III, Nos. 1, 2, 3, and 4; July, October 1905; January, April 1906.
1906–1907: Vol. IV, Nos. 1, 2, 3, and 4; July, October 1906; January, April 1907.
1907–1908: Vol. V, Nos. 1, 2, 3, and 4; July, October 1907; January, April 1908.
1908–1909: Vol. VI, Nos. 1, 2, 3, and 4; August, November 1908; February, May 1909.
1909–1910: Vol. VII, Nos. 1, 2, 3, and 4; August, November 1909; February, May 1910.
1910–1911: Vol. VIII, Nos. 1, 2, 3, and 4; August, November 1910; February, May 1911.
1911–1912: Vol. IX, Nos. 1, 2, 3, and 4; August, November 1911; February, May 1912.
1912–1913: Vol. X, Nos. 1, 2, 3, and 4; August, November 1912; February, May 1913.
1913–1914: Vol. XI, Nos. 1, 2, 3, and 4; July, October 1913; January, April 1914.
1914–1915: Vol. XII, Nos. 1, 2, 3, and 4; July, October 1914; January, April 1915.
1915: Vol. XIII, Nos. 1 and 2; July, October.
1916: Vol. XIV, all twelve issues.
1917: Vol. XV, all twelve issues.
1918: Vol. XVI, all twelve issues.

THE JOURNAL OF ORTHOPAEDIC SURGERY

1919: Vol. I, all twelve issues.
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THE JOURNAL OF BONE AND JOINT SURGERY

1922: Vol. IV (Old Series Vol. XX), Nos. 1, 2, and 3; January, April, and July.
1923: Vol. V (Old Series Vol. XXI), Nos. 1, 2, 3, and 4; January, April, July, and October.
1924: Vol. VI (Old Series Vol. XXII), Nos. 1, 2, 3, and 4; January, April, July, and October.
1925: Vol. VII (Old Series Vol. XXIII), No. 1; January.
1926: Vol. VIII (Old Series Vol. XXIV), Nos. 1, 2, 3, and 4; January, April, July, and October.
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1928: Vol. X (Old Series Vol. XXVI), Nos. 1, 2, and 3; January, April, and July.
1929: Vol. XI (Old Series Vol. XXVII), Nos. 1, 2, and 4; January, April, and October.
1930: Vol. XII (Old Series Vol. XXVIII), Nos. 1 and 2; January and April.
1931: Vol. XIII (Old Series Vol. XXIX), No. 1; January.
1932: Vol. XIV (Old Series Vol. XXX), No. 4; October.
1933: Vol. XV (Old Series Vol. XXXI), No. 1; January.
1934: Vol. XVI (Old Series Vol. XXXII), No. 4; October.
1935: Vol. XVII (Old Series Vol. XXXIII), Nos. 1, 2, 3, and 4; January, April, July, and October.
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1940: Vol. XXII (Old Series Vol. XXXVIII), No. 1; January.
1941: Vol. XXIII (Old Series Vol. XXXIX), No. 1; January.
1944: Vol. XXVI (Old Series Vol. XLII), Nos. 1, 2, 3, and 4; January, April, July, and October.
1945: Vol. XXVII (Old Series Vol. XLIII), No. 2; April.
1947: Vol. XXIX (Old Series Vol. XLV), Nos. 1, 2, and 3; January, April, and July.
1948: Vol. XXX-A, No. 1; January.

Any reader having copies of the above, which he is willing to dispose of, is requested to correspond with the Editor.

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New MOSBY Books

Bateman—The Shoulder and Environs

By James E. Bateman, M.D., F.R.C.S. (C). *Diplomate American Board of Orthopedic Surgery, Fellow American Academy of Orthopaedic Surgeons; Orthopedic Consultant, Sunnybrook Hospital, Toronto. Department of Veterans Affairs of Canada; Consultant, Workmen's Compensation Board of Ontario.* 550 pages, 376 illustrations. Price, $16 25.

The book includes everything from Embryology to Assessment of Disability as applied to the shoulder area. The area itself has been interpreted more as the forequarter rather than a single joint.

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Rehabilitation of the shoulder has been stressed. Exercise, physiotherapy, and occupational therapy routines are included.

Scuderi—Atlas of Orthopedic Traction Procedures

By Carlo Scuderi, B.S., M.D., M.S., Ph.D. *Clinical Associate Professor of Surgery, University of Illinois; Professor of Surgery, Cook County Graduate School.* 229 pages, 124 illustrations. Price, $12.50.

Gathered in this volume are the important features essential for successful use of orthopedic traction procedures. The illustrations concisely demonstrate the necessary features. Opposite the illustrations are given clear descriptions of the devices and the principles involved.

The purpose of this book is to fill a definite gap in orthopedic literature by photographs, line drawings and simple descriptive language. With the present training program in both the general surgical and orthopedic surgical specialties, the teaching of traction procedure for each specific indication at times becomes a Herculean task for the teacher. This type of book should facilitate the teaching of students, interns, and residents in the fracture and straight orthopedic services. It should also be of great help to the nursing profession and physical therapists who work with these patients.

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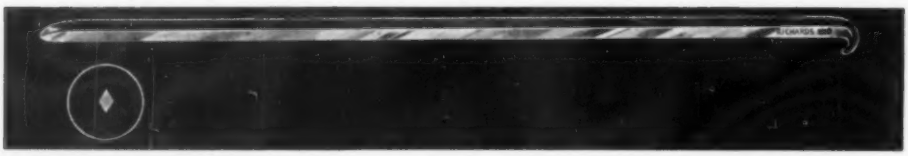

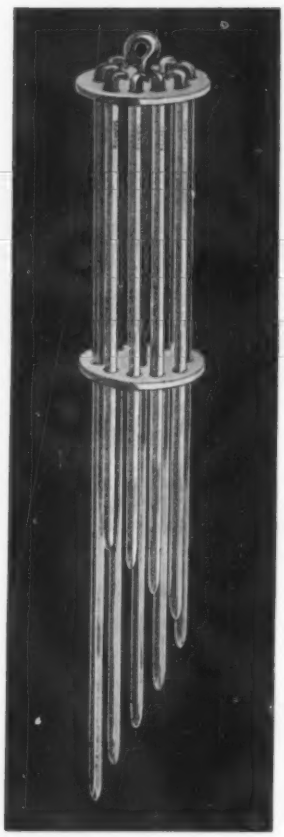

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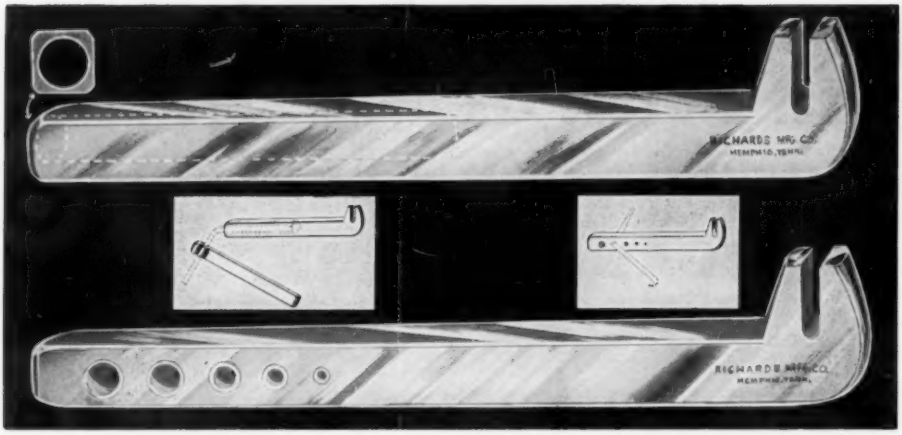

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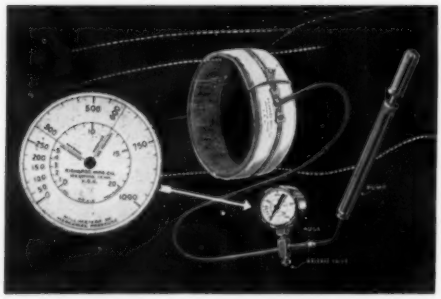

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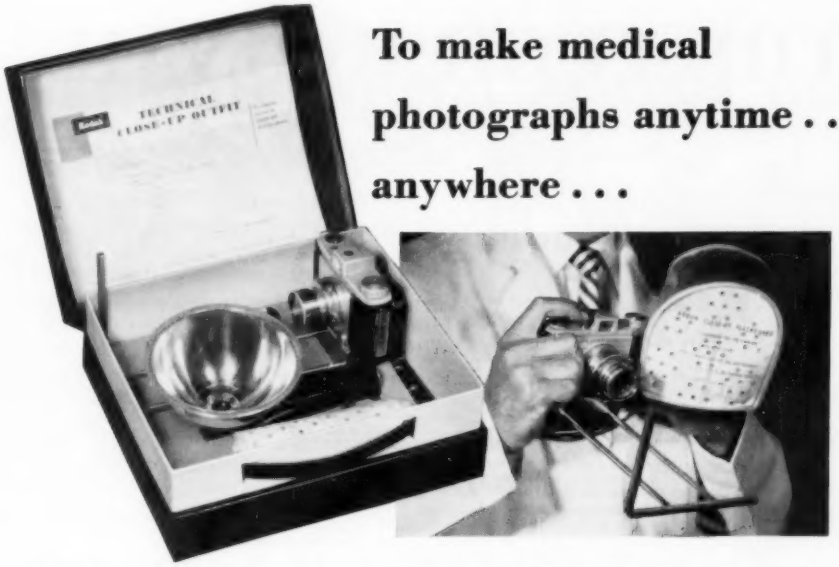

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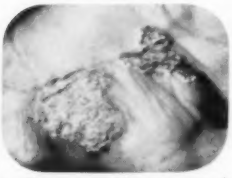

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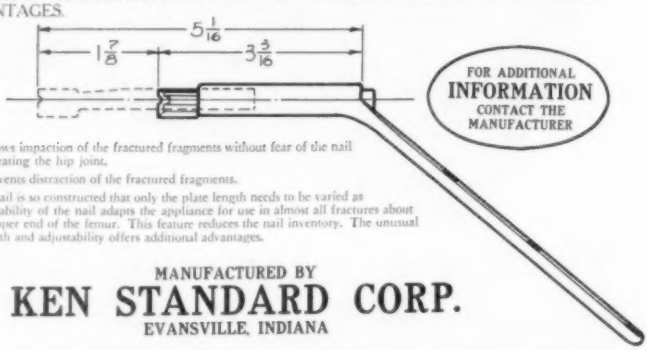

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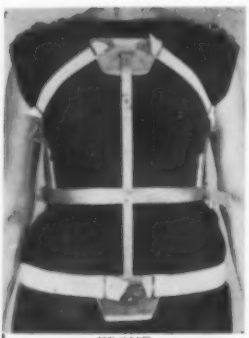

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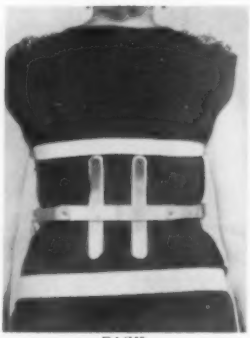

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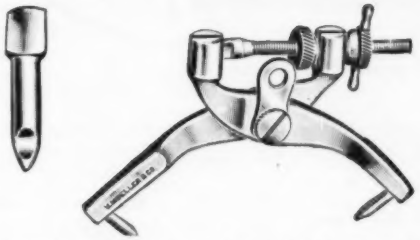

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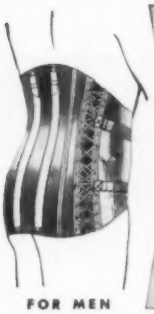

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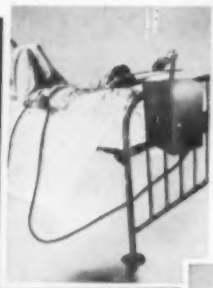

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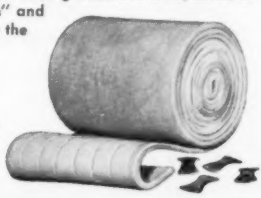

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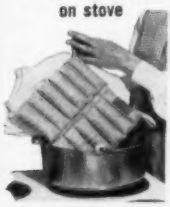

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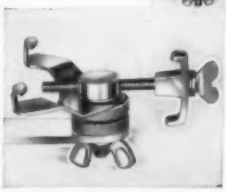

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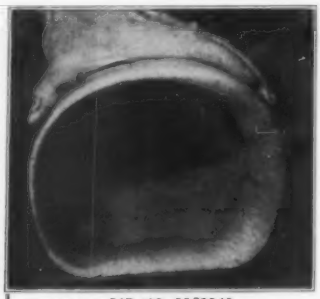

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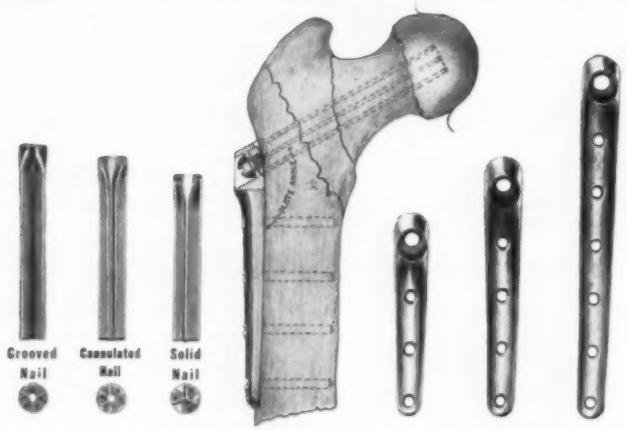

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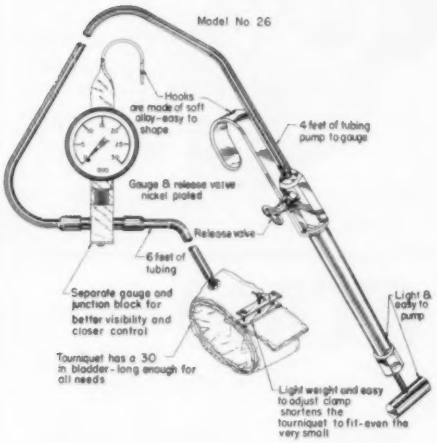
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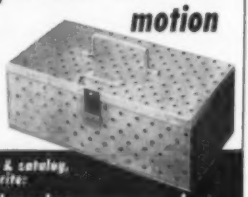

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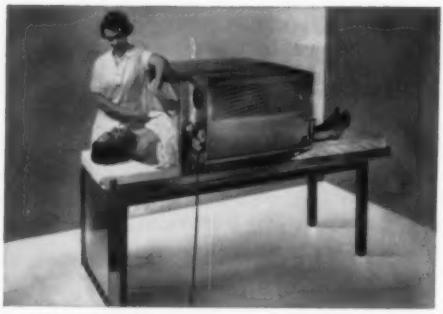

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